The light of SESAME: A dream becomes reality

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Summary. — The foundation of the international SESAME synchrotron laboratory in Jordan is described including political, technical, scientific and financial aspects. Following the model of CERN, its objective is not only to promote science but also bring people together from countries with different traditions, religions and mentalities. To create an international organisation in the Middle East and North Africa (MENA) region required sometimes quite unconventional procedures not disclosed in any official document. Because of the exceptional circumstances, a more detailed description of its history may be of interest. Although its success was doubted by many at its start, the facility will start operation in spring 2017.

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1. – The first ideas

Sometimes the most risky and improbable initiatives have a chance to succeed if the time is ripe and if the right persons get involved. This happened to become true for SESAME, the international synchrotron radiation laboratory in Jordan. It grew out of some vague ideas more than a decade ago and is ready to start operation in 2017. In a region which is politically in turmoil and where SESAME contributes to a better understanding between people of different traditions, mentalities and political systems. The history of founding an international centre under such conditions and in this region has many aspects: political, scientific, financial, bureaucratic and last not least human. This report will try to give an impression of the difficulties encountered and how they were solved, sometimes using unconventional ways. It will give some examples how essential decisions are not taken in formal meetings but at informal conversations, at dinners or coffee breaks, nowhere recorded in official minutes.

As early as in the 1980’s the theoretical physicist Abdus Salam, Pakistani, Nobel Prize Laureate and best known in Italy as founder of the International Centre for Theoretical Physics ICTP at Trieste (fig. 1) suggested to establish a synchrotron radiation facility in Jeddah (Bahrain) in the Middle East, motivated by the fact that this region was lacking any major research facilities. Such a possibility was again suggested during a meeting with Turkish parliamentarians at Istanbul by A. Salam with the argument that the Quran requested to investigate nature. At the same meeting H. Schopper raised the question whether the Arab countries would not consider a rebirth of the glorious time about 1000 years earlier when they were leading science in the world. However, all these encouragements remained without any follow up. The time was not yet ripe!

It took about a decade before the principles demonstrated in the foundation of CERN were remembered, combing the promotion of science with the task to a form a bridge to peace. The concept to apply this idea to the Middle East was born as many other great ideas in the corridors and cafeterias at CERN. There in 1994 the late Sergio Fubini, theorist at CERN and professor at the University of Torino, and Eliezer Rabinovici, professor of theoretical physics at the Hebrew University in Jerusalem, met and cooked up an idea how to improve the Arab-Israel collaboration. They decided to establish the committee for Middle Eastern Scientific Collaboration (MESC) which became official by the signature of an agreement at Cairo in November 1995 and which resulted in a high quality meeting at Dahab (Egypt) where Venise Gouda, Minister of Higher Education of Egypt, confirmed her support for the Arab-Israeli cooperation (fig. 1a). Unfortunately violence broke out again in the region and MESC meetings had to be organised elsewhere.

At a MESC round table discussion in Torino Gustav-Adolf Voss from DESY (Hamburg) revived the old Salam proposal to build a synchrotron radiation facility in the Middle East. He and Herman Winnick from SLAC (USA) were members of an advisory
committee of the German facility BESSY I at West Berlin and at a meeting they learned that after the Unification of Germany a more powerful facility would be built in East Berlin. Since it turned out that the operation of two machines was too expensive it was decided to decommission BESSY I. Since BESSY I was still fully engaged in research Voss and Winnick suggested in September 1997 to transfer it to the Middle East and Voss tried to create interests in the MENA region. However, he remained without a positive response from the region.

This creative proposal fell on fertile ground when repeated at another MESC seminar in November 1997 at Torino attended by about 30 scientists from Israel and Arab countries. It was decided to set up a steering group and Fubini asked Schopper to chair it with the arguments that this project was too complicated for MESC and that he now had sufficient time and experience having just retired as CERN DG [1].

2. – SESAME’s position in the large family of synchrotron light sources

Before continuing with the history of SESAME it might be useful to discuss shortly the different classes of synchrotron light sources and how SESAME fits into the overall situation of these multifunctional light sources.

If an electron is accelerated it emits photons. When oscillating in a linear radio antenna with a certain frequency it emits an electromagnetic dipole radiation with the corresponding frequency. An electron which travels on a circular orbit kept there by a magnetic field experiences a centripetal acceleration and emits also an electromagnetic radiation. If the electrons move at speeds close to the speed of light this radiation becomes strongly focussed tangentially to the electron orbit because of relativistic effects (fig. 2). This radiation was observed for the first time in 1947 in a synchrotron and therefore is called “synchrotron radiation” or SR. It has some very special properties compared to other light sources [2]:

![Fig. 1. – a) Abdus Salam. b) E. Rabinovici, Egyptian politician, S. Fubini (from the left) at Dahab meeting.](image)
Fig. 2. – Production of electromagnetic radiation by accelerated electrons: a) in antenna, b) in synchrotron.

- It is strongly collimated in the direction of the emitting electrons
- it covers a broad continuous spectrum of wave lengths from the infrared over the visible to X-rays.
- the radiated power is many orders of magnitude higher than what can be obtained with conventional sources
- it is linearly polarised in the plane of the electron orbit
- it has circular polarisations with opposite signs above and below the orbit plane
- it can be pulsed in time

The detailed properties can be calculated straightforward from classical relativistic theory although the resulting formulae are somewhat complicated.

Since the first observation of SR this radiation has been a nuisance for particle physics since in those accelerators it is an undesirable energy loss which must be continuously compensated and limits the highest energies obtainable. Later its advantages for all kind of investigations were realised and now SR light sources have become one of the most important tools in many sciences.

During the period from 1965 to about 1975 many of the particle physics machines for electrons were used also for SR, albeit only in a “parasitically” mode implying that these first generation SR machines were not optimised for SR research. In particular the energy of the electrons was chosen by the particle physicists according to their priorities. Some of them were accelerators and others electron storage rings. The electron energy was increased eventually from about 1 GeV to 2 GeV and finally to 8 GeV.

The second generation of SR facilities was built in the following years until about 1990 and were optimised as dedicated light sources. Some were already equipped with insertion devices. The energy was not increased further since too high energies are not useful or even damaging for the specimen to be investigated. The broad spectrum is characterised by a “characteristic” or “critical” wavelength given by \( \lambda_c = \left( \frac{4\pi R}{3} \right) \gamma^{-3} \) with the bending radius \( R \) and \( \gamma = E/mc^2 \) and has a maximum at 0.42\( \lambda_c \). The intensity drops very fast below \( \lambda_c \) but experiments can be performed at wavelengths as low as 0.1\( \lambda_c \). For large wavelengths the intensity remains high down to the infrared domain.
Fig. 3. – The evolution of SR sources. SESAME belongs to the third generation.

In the design of the third generation of SR facilities the parameters of the facility were chosen according to the users’ interests concerning the choice of the electron energy and the beam optics.

The total power emitted in the bending magnets is $P \propto E^4 \times R^{-2}$ where $E$ is the electron energy and $R$ the bending radius which is proportional to $1/B$. Hence the choice of these parameters is a compromise between a large $E$ (strong radiation, short wavelengths) and $B$ (expensive magnets to keep $R$ small). One might consider machines with $E > 5$ GeV specialised for hard X-ray spectroscopy and machines with $E$ between 2 and 3 GeV useful for the broad spectrum except the highest energies. SESAME belongs to the latter class of SR sources (fig. 3).

Since the region of X-rays is extremely interesting one possibility to obtain short wavelengths is to increase the electron energy, but an expensive choice. This objective can also be achieved by adding additional insertion devices in the straight sections between the bending magnets, an opportunity which does not only reduce the usable wavelengths without increasing the electron energy but can also increase the brightness of the beams or even produce coherent radiation (fig. 4).

The first possibility is a wiggler—a series of magnets with periodically opposite polarities, from a few periods to about a dozen. These will deviate the otherwise straight path of the electrons in a wavy way and if the parameters are properly chosen the circulating electron beam is not essentially disturbed. But at the location of each of the wiggler magnets SR is produced and usually the wiggler is designed so that the peak magnetic field is greater than the field in the bending magnets. One can even use superconducting wiggler magnets with considerably higher magnetic fields than in the bending magnets. Bending magnet fields are typically in the range 5 to 15 kG whereas conventional electromagnet wiggles use fields up to about 20 kG and superconducting wiggles reach up to 60 kG. The result is still a broad spectrum but it extends to much higher photon energies. Thus shorter wavelengths in the X-ray region can be produced even at a machine with modest electron energies in the range of 2 to 3 GeV like SESAME.
In addition the intensity is increased practically proportional to the number of periods in the wiggler. Since the angular spread of the wiggler radiation is rather wide it is possible to install two beams on the same wiggler.

A second option for an insertion device is the undulator. The electrons in a synchrotron or storage ring are not distributed uniformly along the circumference but are concentrated in small bunches by the accelerating RF cavities. Each bunch produces a flash of SR which in a wiggler emits the light incoherently. In an undulator the geometry is changed in such a way that the light produced by different bunches can interact coherently. The condition for the coherence of the light emitted from two different bunches is that the difference between the time the electrons (with $\beta = v/c$ and $\gamma = E/mc^2$) need to traverse one magnetic period of the undulator, the “undulator period” $\lambda_u$ and the time it takes for the light to travel the same distance is equal to one oscillation period of the SR which gives $\lambda_u/\beta c - \lambda_L/c = \lambda/c$ where the first term is the flight time of the electrons/period and the second the time for the photons for the same period. For $\beta$ close to 1 this gives approximately $\lambda = \lambda_u/2\gamma^2$. This condition is fulfilled only for one wavelength and therefore the radiation is monochromatic. But since the coherence condition might also be matched for higher harmonics the spectrum can consist of additional lines although with lower intensities. The coherence leads to a much reduced angular spread and in addition concentrates most of the photons in a narrow line of wavelengths and hence the power of the radiation is even greater compared to wigglers. This allows to use relatively weak magnets in undulators, but in order to obtain a small wavelength it is favourable to use short $\lambda_u$, i.e. short magnets. The details of undulator optimisation for different applications cannot be discussed here.

The most recent advances in synchrotron radiation facilities are the development of free electron lasers where an electron beam traverses an undulator positioned in a resonant cavity, which gives rise to stimulated X-radiation with very narrow bandwidth and extremely high intensity.

For the 3rd generation of SR light sources great emphasis was put on the use of wigglers and undulators requiring long straight sections between the bending magnets.
and a small beam emittance (product of electron source size and beam divergence). This was kept in mind when the parameters for SESAME were chosen and consequently SESAME allows the installation of wigglers and undulators and hence it belongs to this class of facilities which includes more than 60 such facilities in the world.

For scientists interested in X-rays the ideal radiation source has a high brightness (large flux of photons per second within a small solid angle from a small source) which is essential for high-resolution X-ray spectroscopy. To achieve this the synchrotron must have a small emittance. The necessary beam optics is easier to achieve in machines with a large circumference which is one reason for the tendency to build larger machines even when this is not needed from an energy point of view\(^1\). These has led to the construction of a few very large SR sources in the whole world with cost in the several hundred million $ range (fig. 3, Advanced Photon sources) which is beyond the possibilities of SESAME.

3. – A difficult birth

As predictable many people prophesied a number of serious problems and indeed many of them, expected or completely unpredicted, appeared. As a first step Schopper received informal confirmation from the German authorities that indeed BESSY I was to be closed down and scrapped in 1999 and he learned that a request to donate it for a project in the Middle East would be considered favourably. It seemed that the only chance to realize this project in a troubled region was to follow the procedure of the CERN foundation and use UNESCO as umbrella. Schopper proposed Fubini to write a common letter to Federico Mayor, the Director General of UNESCO, which was done on 6 January 1998. Mayor, a scholar himself, answered not only positively but even enthusiastically (fig. 5).

As a next step it was important to find out whether there was sufficient interest among the scientists of the region or whether such a facility would become a “white elephant” not being used. To sound this out, an informal meeting in the frame of a MSC Workshop was organised in Uppsala on 22–26 April 1998 by Thord Ekelöf, a Swedish physicist working at CERN. The outcome of this meeting was quite positive and it was decided to continue with the project.

In August 1999 another preparatory meeting was organised in Berlin at BESSY I with the main task to discuss possible parameters of the machine. It was agreed that BESSY I should not just be reinstalled but that its beam energy should be increased from 0.8 GeV to 1 GeV. Possible beamlines were considered and a users’ community of about 150 scientists was identified. Also a name was chosen. Schopper insisted that an attractive acronym should be found which would have an emotional meaning in different cultures. Impassive acronyms like CERN cannot motivate people without explanations and might even be misleading\(^2\). The name “SESAME” was proposed and accepted since from the tales of One Thousand and One Nights it is known in both cultures, the Arabic and the

\(^{1}\) A particular case is the storage ring PETRA at DESY. It was built for an energy of 20 GeV and a circumference of 2.3 km for particle physics. After it had been stopped for these kinds of physics in 1986 it became one of the best dedicated sources for synchrotron radiation. Its large circumference allows to achieve an extremely small emittance at an energy of 6 GeV.

\(^{2}\) It is almost forgotten that “CERN” stands for Conseil Européen pour la Recherche Nucléaire which created some opposition because of the “N”. The neighbouring population thought for some time that the task of CERN was the development of nuclear energy. Fortunately “CERN” has become a mark of quality, but this took several decades.
Western, as “door opener”. The official name of the laboratory “Synchrotron-light for the Experimental Science and Applications in the Middle East,” abbreviated by SESAME, was invented only afterwards, matching the acronym.

3’1. UNESCO gets involved. – Following Fubini’s and Schopper’s letter Federico Mayor invited all governments around the Mediterranean and in the MENA region to a consultative meeting at UNESCO Paris in June 1999. The project was welcomed and it was decided to set up an Interim Council IC with the task to work out a proposal for the establishment of an international organisation in the MENA region to be submitted to the plenary meeting of UNESCO. This event may be considered as the conception of SESAME, if not its birth, but certainly F. Mayor should be considered as one of its founding fathers. Unfortunately Fubini could not continue to participate in the establishment of SESAME because of bad health followed by a premature and much regretted death.

The following 13 States announced to join the IC and hence became preliminary Members: Armenia, Cyprus, Egypt, Greece, Iran, Israel, Jordan, Morocco, Oman, Palestinian Authority and Turkey. Some countries expressed interest to join later: Algeria, Bahrain, Sudan, UAE (United Arab Emirates) and Yemen, but only Bahrain joined. Armenia, Morocco and Oman dropped out after a site had been chosen.

Other countries from outside the MENA region agreed to become Observers: Germany, Italy, Japan, Sweden, and USA. Later further states became observers: Brazil, China (People’s Republic of), the European Union, France, Greece, Italy, Kuwait, Portugal, Russian Federation, Spain, Switzerland and the United Kingdom.

At the first meeting of the Interim Council in June 1999 H. Schopper was appointed as Chairperson of the IC which held the following meetings at Paris (December 1999), Amman (June 2000), Yerevan (November 2000), Cairo (March 2001), Amman (August 2001) before it was transformed into the final SESAME Council in 2003.

On 1 January 2000 Koichiro Matsuura from Japan followed F. Mayor as Director General of UNESCO. Although educated as a lawyer and a diplomat by profession he gave during his full mandate of 6 years full support to SESAME which became one of the crucial conditions for the success of the project.
3.2. The BESSY I story. – The Interim Council had to face a first serious and unexpected problem during its meeting in December 1999. The German Federal Ministry of Education and Research had agreed to give the components of BESSY I, which had stopped operation in November 1999, to SESAME as a gift, although Poland and Spain had also expressed interest. The main components of BESSY I were an injector, a so-called microtron, and a synchrotron with an energy of 0.8 GeV and all the auxiliary equipment (fig. 6). The original value was about $60 millions. This decision was of course, appreciated by all IC members. However, the gift was given under the condition that the cost of the careful dismantling including documentation, packing and transport, had to be provided by SESAME\(^3\). This had to be done by experienced people in a proper way. Since BESSY had no staff for such an operation, it was proposed to engage experts from Novosibirsk and Armenia who knew the facility, to perform this task. They would have to be paid and the cost was estimated at $600 000. This amount had to be guaranteed by SESAME before the end of 1999 since the building of BESSY I had been promised to the Max Planck Society.

Informed about these conditions just before the IC meeting, Schopper asked for voluntary contributions to save the project. This was of course, an extremely arduous request since usually delegates to such a meeting do not have the power to take financial decisions. After a lengthy discussion the members of the Interim Council and the US State Department, Sweden and Russia agreed to provide a total of $200 000 \(^3\). Since this amount did not cover the total cost of dismantling BESSY I, a precipitate end of the project seemed imminent. To save the project Schopper saw only one possibility. He asked instantly during the IC meeting Koichiro Matsuura who had followed Mayor as UNESCO DG, for an emergency meeting. Invited to lunch Schopper warned Matsuura at the entrée that this might become an expensive lunch. After having explained to Matsuura the conditions of the German government, Schopper asked for the missing

\(^3\) If no other institutions had expressed interest, BESSY I would have been scrapped without care and documentation and the scrapping would have been paid by selling the recuperated copper and iron.
Matsuura confirmed his full enthusiasm for the project, not only by nice words but by agreeing to this almost impossible request. The IC was informed about this courageous decision after lunch and accepted it with great satisfaction.

Later the German and French Ambassadors to UNESCO, not being well informed about SESAME, complained formally that Matsuura had not followed the rules of UNESCO by making this decision without the appropriate consultations. Schopper had to explain to them the difficult conditions required by the German government and ask them to withdraw their complaints, what they did. Matsuura could provide this money without formal approval by the UNESCO authorities since the Japanese government had given him a considerable sum to be used at his discretion when he was appointed DG of UNESCO.

The dismantling of Bessy I could start and was done by the Russian and Armenian experts and the many boxes were waiting for the transport.

However, serious public criticism was raised in Germany and the government was asked to withdraw the authorization of export of this material. Some scientists (e.g. in an article by a chemist Brandt from Marburg in the “Tagespiegel”) claimed that it is possible to produce nuclear materials for atomic bombs with SESAME. This delayed the formal authorisation for the export of BESSY I by several weeks. Schopper was invited to a discussion on German TV with Brandt where he had to admit that with SESAME single atoms of uranium or even plutonium can be produced, but not a sufficient number for a bomb. If this were possible, one could also produce gold in quantities which would solve all financial problems of SESAME. Fortunately these objections could be discussed and solved in a rational way.

So finally the BESSY I components were shipped from Berlin to Hamburg where they could leave the harbour on 7 June 2002, one ship full of containers (fig. 7). They were transported to Zarqa Free Zone in Jordan where they were kept in custody by the Jordanian government until SESAME was formally founded and the building ready to accept the components.
4. – The formal foundation of SESAME by UNESCO

According to UNESCO rules, the foundation of a new international organisation has to be approved by the General Conference involving 195 governments. Before a decision is taken a project has to be submitted to and be recommended by the Executive committee with still more than 50 Member delegates. Since the General Conference meets only every 2 years and rarely accepts a proposal immediately, one could estimate that the approval of SESAME would take several years.

During Mayor’s mandate the responsible contact person at UNESCO was Siegbert Raither (a German physicist), Director of the Department for Mathematics, Physics and Chemistry. After Matsuura had become DG it was Prof. Maciej Nalecz (a Polish biologist), Director for Basic Sciences and Engineering, who was nominated as Representative of the UNESCO DG in the SESAME Council (fig. 8). Both were fully engaged in the SESAME project and contributed enormously to steer it around all kinds of bureaucratic traps and unforeseen difficulties. Both became irreplaceable and were essential for the successful foundation of SESAME. Clarissa Formosa-Gauci of UNESCO became the secretary to handle the Council business becoming a steady and indispensable element in the history of SESAME (see fig. 25).

4'1. The formal approval of the statutes by UNESCO. – Since the CERN convention has proven itself as an extremely successful basis for international cooperation combining the two objectives, promoting science and bringing people together, Schopper copied more or less the CERN convention for SESAME. Only a few minor changes were applied to meet better the special conditions of SESAME. Each Member has one vote independent of its size and can send two delegates to Council meetings, one government representative and one scientific advisor. One addition was that a representative of the DG of UNESCO became the representative of UNESCO DG and had voting rights. The reason was that in this way a stronger influence of UNESCO was established which could be helpful to mitigate in case of political difficulties. Fortunately the same spirit as in CERN Council was introduced, meaning that practically all votes were taking unanimously. In case of serious conflicts an alternative solution was looked for which was acceptable to most Members.

Of course, the Statutes had to be carefully scrutinised by the legal department of UNESCO. One day Nalecz asked Schopper to accompany him to the legal advisor in order to be able to answer questions. Arrived at the Advisor’s office he immediately
broke out into a hard criticism without a polite introduction and presentation. He stated that the proposed statutes were extremely bad and when asked whether he knew better examples he showed without hesitation a copy of the CERN convention. When Nalecz asked him whether he knew who his companion was, he answered negatively. Nalecz introduced Schopper as former DG of CERN who explained that he had copied the CERN convention. Great embarrassment! After a short discussion the SESAME Statutes were approved.

One of the few political problems which came up during the formal approval of SESAME was the name of Palestine. In the Interim SESAME Council one could easily come to an understanding that the name “Palestine” should be used since the common agreement was to keep political questions out of the daily Council business. However, when it came to the approval of the statutes by UNESCO the politically correct names of the states had to be used. The proposal to follow the practice of the General Assembly of UN which had adopted the name “Palestine” was not operative for UNESCO since here Israel had not accepted it. Schopper was finally sitting in an office in Amman connected by one phone with President Arafat (still alive at that time) and by another line to the Ministry in Jerusalem discussing which name should be used in the SESAME Statutes. After long deliberations both sides agreed to refer to “Palestinian authorities on behalf of the PLO”. The problem came up later again when UNESCO officially accepted the name “Palestine” and the Palestinian delegation in the SESAME Council asked that it should be adopted also by the SESAME Council. Fortunately they could quickly be convinced by the President Llewellyn-Smith that it would be awkward to go to all the governments and parliaments of the SESAME Members and ask for a change of the statutes.

After all the SESAME Members had accepted the Statutes the definite approval by UNESCO was still missing. After considerable lobbying to accelerate this procedure, the Executive Committee recommended to the General Assembly in November 2001 to approve SESAME in principle and instead of waiting for the next General Assembly in 2003, to authorise the Executive Board(4) to take the final decision after clarification of some remaining details at its next session. This happened in May 2002 with the statement: “SESAME is […] a model project for other regions […] a Quintessential UNESCO project combining capacity building with vital peace-building through science.” It was also suggested that UNESCO should provide seed money for similar projects in other countries (e.g. South Africa). It was one more miracle that this decision could be obtained in less than two years!

4.2. Members and observers. – According to the constitution, the UNESCO decision was to become effective when at least 6 governments sustained by their parliaments had submitted official letters to the Director General of UNESCO declaring their intention to join SESAME. This happened in 2003 with the founding Members Bahrain, Egypt, Israel, Jordan, Pakistan, Palestine, and Turkey which were joined later by Cyprus and Iran (fig. 9). The initial Observers were Oman, UAE and Morocco which were joined later by France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russia, Sweden, UK, USA and finally EU.

The official foundation date of SESAME is 6 January 2003 when the Interim Council was converted into the SESAME Council, only after 4 years since the first proposal —a remarkable short time.

(4) UNESCO Executive Committee 162 EX/49.
A particular problem turned up when Japan considered to join SESAME. Japan wanted to be sure that Observers cannot be obliged by Council to contribute to the yearly budget. They asked for a special council decision declaring that Japan would be exempted from future decisions asking for contributions. Secondly, in the Statutes a phrase was taken over from CERN to discouraging Members to put unfair pressure on the Director and staff of the centre. This was interpreted by the Japanese as a kind of mistrust assuming that they would try to exert such unfair pressure. Fortunately after some discussions between UNESCO and Japanese lawyers a solution without changing the Statutes could be found.

Attempts to win other countries (e.g. Morocco, Iraq, Saudi Arabia, and Yemen) as SESAME Members remained so far without results. In many discussions they expressed great interest in the scientific goal of the laboratory but negative political considerations were considered to be dominant.

5. – The site selection

Before SESAME could be the formally approved by UNESCO, a major problem had to be solved first — finding a host state and a site. For an international laboratory this is a particularly delicate question since factual arguments get mixed with political aspects.

5.1. Site criteria. – The Interim Council agreed on certain criteria which had to be satisfied by the host country and the site:

- the laboratory must be accessible to all scientists from all over the world
- the site should be located geographically as central as possible
- the authorities of the host state should strongly be committed to the project
- a special contribution is required by the host country: free ground and main building
- the technical infrastructure (water, electricity, access roads) must be provided.
Seven Members (Armenia, Egypt, Iran, Jordan, Oman, Palestine and Turkey) proposed 12 sites. In order to find out which countries were willing to accept these criteria and were able to fulfil them, Maurizio Iaccarino, UNESCO Assistant Director General for Natural Sciences, and Herwig Schopper visited Egypt, Israel, Jordan and Palestine in September 1999. The situation in Armenia, Iran and Turkey was explored at the occasion of meetings of the Interim Council or other meetings.

In Egypt the Atomic Energy Authority and the Academy of Sciences were responsible for contacts with SESAME. Three possible sites were visited and a meeting with the Minister of Higher Education and Scientific Research, Moufid Shebab, was arranged. He expressed the strong interest of Egypt to host SESAME, but a consultation with various other authorities would be necessary before the project could be presented to the Prime Minister for a decision. It became clear that a long procedure was inevitable.

The meeting with the Palestinian National Authority took place at Ramallah with the Minister for Higher Education Munther Sala and professor Said Assaf who arranged also a visit with President Arafat in his private home (fig. 10a) which was also attended by the Minister of Planning and International Cooperation, Nabeel Shaath. They went so far as to declare that some funds (a total of about $20 millions) provided by the German Government for infrastructure projects which did not progress well could be transferred to SESAME. However, later it turned out that this transfer was not possible since the original funding had been approved by the German Parliament for specific projects and could not be transferred.

In Israel meetings at Jerusalem were arranged with representatives of the Ministry of Science (i.e. Prof. Bishari, N. Sherman, J. van Zwarenstein) and members of the Israel National Committee for Synchrotron Radiation (M. Deutsch and E. Rabinovici). The attitude of Israel towards SESAME was explained, namely a strong interest, however, no site would be offered for obvious political reasons. There was also another problem. Israel was already strongly involved in the ESRF laboratory at Grenoble and there considerable funds were contractually bound. For all activities in synchrotron radiation the Academy of Sciences was responsible. At a meeting organised by the Academy it was not easy to convince the biologists that Israel would benefit from SESAME since most of them had easy access to other laboratories all over the world. However, the President of the Academy Jacob Ziv expressed the view that they would certainly use SESAME as soon as it would be working because of the near distance to Rehovot. The biologists agreed finally under the condition that it would not take more than a few hours to get a specimen into a beam. This required that the Allenby Bridge across the Jordan River should be opened for SESAME personnel. This could be achieved and the bridge can now be used by Israelis working at SESAME. So SESAME has demonstrated that it helps to open not only doors but even bridges!

Armenia was a special case since close relations existed already with European institutes. There was a Synchrotron Laboratory at Erevan which had close connections to European labs in particular with DESY at Hamburg. Since their accelerator was outdated they offered its building and infrastructure for SESAME. Their proposal was strengthened by the support of Mr. Hovnanian, a rich Armenian living in the USA, who offered considerable financial support. However a closer inspection of the building revealed that many alterations would have been necessary to make it useful for synchrotron radiation beams and SESAME.

In Iran several visits took place and a user workshop was organised although at that time Iran was considered as a rogue country. Strong interest was found among the scientists and government representatives, they decided to join SESAME and a site
was offered. But since it was hardly possible to grant access to all scientists from the world the site proposal was not considered. However, Iran participated actively from the beginning in all the activities of the project.

In Jordan A. Badran who had just returned from UNESCO as Deputy DG organised a meeting with representatives of universities and other organisations. There many misconceptions about SESAME could be clarified. However, no members of the government could be met and no commitment was obtained. Since Jordan was the most promising country as far as free access by all scientists was regarded, Schopper was desperate about this negative outcome. The story how SESAME in the end came to Jordan merits its own chapter since it is an elucidating example how decisions are sometimes taken in reality, not as being cited in official documents.
5.2. A former student saves the project: the Isa Khubeis story. – When Schopper was professor in 1958 at Mainz in Germany he had a Jordanian student, Isa Khubeis, who passed there the diploma examination. He followed Schopper in 1961 to Karlsruhe and received from this university the PHD. After returning to Jordan he advanced soon to Professor at the university at Amman and finally he became Vice-President of Al-Balqa Applied University at Allan near Salt, the former capital of Jordan, located about 20 km from Amman. He had difficulties to become President in a Jordanian university since he was a Coptic Christian (his first name Isa is the Arabic version of Jesus).

Since Schopper and Khubeis always had good relations becoming in the end friends, Schopper called him in a last desperate effort just before leaving the country. After having learned about the site problem, Khubeis (fig. 10b) invited the same evening Iaccarino and Schopper to dinner in his home. Another couple appeared and was presented as Khaled Toukan, President of Al-Balqa University, and his wife. They were served an excellent meal by Isa’s German wife and the dinner came almost to an end when another guest turned up. They were somewhat astonished to see the new guest wearing a jogging suit coming from his daily training. It turned out that it was Prince Ghazi Bin Muhammad who chaired the Governing Board of Al Balqa University and apparently was a close adviser of King Abdullah II. Schopper explained to him the purpose of SESAME and after carefully listening he disappeared with his mobile phone on the terrace. Coming back he simply announced: tomorrow at 11 o’clock you have an audience with H.M. the King, but adding “tomorrow you will not recognise me”. He explained that besides advising the King on scientific matters he was also the contact person with the Bedouins and on official business he had to be dressed like a Bedouin wearing turban and dagger (fig. 10c). Next morning Iaccarino and Schopper were taken to the royal palace where they met the King in the presence of Prince Ghazi. Schopper explained to the King the idea of SESAME underlining the conditions a host state would have to meet, emphasising two critical conditions: that every scientist of the world must have access and the host state would have to provide the land and pay for the building. After asking a number of relevant questions the King declared that he was prepared to offer a site. When asked whether he would commit himself in writing he agreed and half an hour later Schopper was handed a letter by Prince Ghazi addressed to the DG of UNESCO signed by the King. This was the practical site decision! What would have happened to SESAME without the former student Isa Khubeis? During the first years of SEAME he was still very helpful, but unfortunately he died soon after several heart operations. He never got full credit for his contribution.

5.3. The formal site decision. – The formal site decision was taken at a restricted meeting of the Interim Council on 10/11 April 2000, at CERN. To concentrate the discussion, only one representative of the Members Armenia, Cyprus, Egypt, Greece,.

(5) In later years Schopper got relatively close contacts to Prince Ghazi who kept strong interest in SESAME and attended often the Council meetings. When asked what his education was, he explained that he had studied philosophy at Oxford and the topic of his PHD thesis was “love, in general terms”. The next question was whether he knew the Swiss writer Denis de Rougemont who had become famous by his books on love, and he replied “My whole thesis deals with the work of de Rougemont but I have never met him”. Unfortunately de Rougemont had passed away recently, otherwise it would have been a pleasure to introduce the Prince to de Rougemont. Schopper had known de Rougemont quite well since he was one of the founding fathers of CERN.
Iran, Israel, Jordan, Oman, Palestinian authority and Turkey were allowed to participate. After long discussions and a series of secret step by step votes, the number of sites was reduced. Egypt and Iran withdrew their proposals before the final vote. In the final secret vote first choice was given to Jordan with the Allan site near Salt and second choice to Armenia with the Yerevan site.

6. – The building

Looking back one may state that the chosen site turned out quite satisfactory. There was sufficient space for the main building and possible extensions and the supply of water and electricity and access roads was guaranteed.

In order to speed up the planning of the main building it was decided to copy an existing building. The ANKA facility at the FZK Karlsruhe in Germany was chosen since it houses a synchrotron similar to SESAME. In addition Dieter Einfeld (who was responsible for ANKA) was appointed as first Technical Director of SESAME and he knew the advantages and disadvantages of the building very well. Thanks to the generosity of the management of FZK Karlsruhe a copy of the ANKA building was made available including several 100 drawings whose explanations, of course, had to be translated into Arab. Based on this documentation the preparations for the building could be sped up considerably and the various authorisations necessary from the Jordanian authorities were obtained within extremely short times.

On 6 January 2003 the ground was broken and H.M. Abdullah II and UNESCO DG K. Matsuura unveiled a marble plate in the presence of delegates of Members and Observers and many future users (fig. 11).

Fig. 11 – UNESCO GD K. Matsuura and H.M. Abdullah II unveil marble plate at ground breaking ceremony in 2003.
As usual no construction can be finished without surprises. The first appeared when the excavation started. For a synchrotron radiation facility it is extremely important that the floor of the machine and the attached beams is extremely stable. Changes of the floor height must be smaller than the dimensions of the beams (a tiny fraction of mm). Indeed a bad surprise came up when it was discovered that the upper layer of the soil was very bad for the foundation of the machine hall and the bad ground had to be removed down to several meters and replaced by a very thick and strong foundation of armed concrete (fig. 12). According to its commitment Jordan was prepared to cover the additional cost, but a certain delay of the construction could not be avoided.

Finally the completion of the main building housing the accelerators, offices, workshops and labs was achieved within 5 years, a success to a large part due to the engage-
ment of the Engineering Department of Al-Balqa University supervised by Rafiq Sarraf. In some European countries just getting the authorisation for such a building would have taken several years. Figure 13 shows the general layout of the building with laboratories and workshops integrated in the machine building. The original plan with the machine in the centre of the building is shown. In addition to the main building two hangars were built to store and test the BESY components. This made it possible that SESAME staff could start at an early time to get familiar with the equipment.

On 3 November 2008 the building was inaugurated in the presence of UNESCO DG Matsuura and H.M. King Abdullah II and many representatives of the Members and Observers (fig. 14). At this occasion the presidency of the SESAME Council was transferred from Schopper to Llewellyn-Smith.

Another bad surprise arrived on 14 December 2013 when, because of an unexpected heavy snowfall mixed with rain and hail, the main girder of the roof of the main building (fig. 15) gave way and came down until it was supported by the already installed shielding wall of the machine. This happened to everybody’s surprise since it was hard to understand why a roof which had withstood the much harsher winters at Karlsruhe and
Fig. 16. – The final SESAME building.

Fig. 17. – Stages of construction of the preliminary guest house.

was designed to carry 30 cm of snow could not survive a snowfall in Jordan. Fortunately no damage was done to the machine components which were already being installed. The solid shielding walls around the booster ring protected the components. Immediate emergency measures were undertaken to shield the machine components from the snow and rain. The installation of the machine could be continued after a relative short time. This event showed that the SESAME staff supported by Jordanian organizations was able to deal with such a major disaster. The accident was investigated by Jordanian experts and an international committee, various reasons were identified and it was de-
cided that a new roof had to be constructed. A compromise concerning the financial consequences was agreed upon implying that about 2/3 of the cost would be covered by the constructor of the roof, partly still under guarantee, and 1/3 by Jordan. This avoided a long procedure in court and the new roof was finished in record time. Thanks to the immediate protection measures no damage had been caused to the machine components and serious delays for the final installation of SESAME could be avoided.

Figure 16 shows the building after the accident as it looks today.

Since there is a lack of hotels in the immediate vicinity, the construction of a guest house for users and also an auditorium are planned. In order to meet the immediate need to house the first users who will come to carry out experiments with the first beams in spring 2017, a small preliminary guest house has been erected recently right at the entrance to the main building in an incredible short time. Figure 17 shows the various phases of its construction.

In summary one can say that Jordan has considerably surpassed the promises of H.M. King Abdullah II. The engagement of Khaled Toukan, the Director of the Institute from the beginning to the present, was an essential element that all this could be achieved in such a short time.

7. – The people involved in the project

To realise a project like SESAME in a region with considerable political tensions, with little scientific tradition and extremely limited financial resources required the engagement of devoted personalities, at different levels of responsibility at different times to solve all the expected and unpredicted problems.

The President of Council is appointed by Council. For the first President it was decided that it should be somebody with experience in managing a large organisation and, to avoid political problems, he should not come from a Member. After having chaired the Interim Council from 1999 H. Schopper was asked to continue as President of the Council. In 2008 after almost 10 years of service he expressed the wish to step down. To keep him engaged he was elected as honorary member of Council for life and was also asked to propose a successor.

Although in principle it would be natural that the President comes from a Member, it was agreed that in the still precarious situation of SESAME it would be suitable to engage again a former Director General of CERN. Thus Sir Chris Llewellyn-Smith (UK) took over on 3 November 2008 and this event was combined with the inauguration ceremony of the SESAME building. He will be followed by Rolf Heuer, another former Director General of CERN, on 16 May 2017 at the occasion of the official inauguration of SESAME. Of course, it should not be considered as a rule that always a former DG of CERN should be President, but for the present time this is still considered as the most helpful practice (fig. 18).

However, it was agreed that the Vice-Presidents should come from Members. The first Vice-President was Dincer Ulkii from Hacettepe University, Turkey. Later it was decided to have two co-Vice-Presidents. The discussion how to appoint them became an outstanding example how international cooperation can be managed by disregarding political issues. Llewellyn-Smith managed to achieve an agreement that the Vice-Presidents should be appointed by consensus and not by vote and if no major reasons stand against it, an alphabetical order should be followed. This would assure that all countries are eventually taken into account. The term of Vice-Presidents would be for 2 years. At the Council meeting in 2011 it was decided that in addition to Tarek Hussein from Egypt whose term
as Vice-President had been extended and still continued, the Iranian Seyed Mahmoud Reza Aghamiri should become co-Vice-President, to be followed in 2014 by the Israeli Eliezer Rabinovici. Later Kamal Araj (Jordan) was appointed as co-Vice-President.

The Director of the laboratory is elected and appointed by Council: Prof. Khaled Toukan, physicist by training, former president of Al-Balqa University, then Minister of Education, now High Commissioner for Nuclear Energy became the first Director and has been extended until the present. His close contacts to the Royal Court and with the Jordanian government were and are still essential for the good development of the laboratory.

Administrative Director: The post was published and in an interview meeting with several good candidates at Alexandria, finally Hany M. Helal from Egypt was elected. He turned out to be an excellent choice and was instrumental in setting up the whole administration of SESAME. He left this post when he was appointed as Minister of Research in Egypt. He was followed by Yasser Khalil also from Egypt who guided the laboratory very well through some stormy waters and he is still in charge of the administration.

Technical Director: The first Technical Director Dieter Einfeld (from Karlsruhe) was essential in designing the concept of the SESAME facility. When he accepted a position at the Synchrotron Radiation Source ALBA in Spain he was followed by Gaetano Vignola from Frascati where he had been responsible for the DAPHNE project. He left for private reasons and was followed in 2004 by Amor Nadji from Orsay in France. When he was offered a leading position in his home laboratory he left. His assignment was taken over by Erhard Huttel from Karlsruhe. All these persons are excellent accelerator experts and the fact that they were offered attractive positions in other laboratories is the best proof of such a statement. SESAME seems to be a favourable place for accelerator specialists to make an interesting career. But, in spite of these frequent changes, the construction
of the machine did not suffer because these experts knew each other since long times, agreed on the technical concept of SESAME and indeed each of them brought in some new fertile ideas.

**Scientific Director:** Since the detailed scientific programme and the concept of first beamlines was not the most urgent challenge in the first years, it was not necessary and indeed difficult to find an expert in synchrotron radiation experiments to fill the post of scientific director. It was more important at those early times to employ somebody with experience in international cooperation. The first scientific director was Aslam Baig from Pakistan who had some experience with synchrotron radiation but his main field was laser physics. He was followed by another Pakistani, Hafeez Hoorani, with international experience obtained at CERN. Both were quite instrumental to get the training programme working. When more recently the setting up of beamlines became a crucial issue it was obvious that a scientist experienced in experiments with synchrotron radiation should be hired and Giorgio Paolucci from Italy accepted the task to get the first beamlines ready at the start of the machine.

**SESAME staff:** From the beginning a great effort was made to involve as many staff from Members as possible in the construction of the machine. Since very few experts were available, an extensive training programme was started as will be reported later. The availability of the BESSY I pre-accelerators at an early time and the task to get its components, the microtron and the booster, working offered excellent possibilities for the staff to get acquainted with accelerators. In the end most of the installation of the components was done by teams from the Members. Because of the restriction of the budget and the consequential limited number of staff, they made sometimes heroic efforts to meet the requirements. This is even truer for those who were hired in recent years to set up the beamlines. In general all staff had to suffer because of the restricted possibilities for the personnel and family life during these years of building up the laboratory was certainly not easy.

The number of staff has grown from the beginning of SESAME to the end of 2016 from zero to 53 and it has to increase further to about 70 when the facility will come into full operation. This is a remarkably small total number of staff for a facility like SESAME.

8. – Technical evolution of SESAME

8.1. *From Bessy I to a 3rd generation synchrotron radiation facility.* – At the Berlin meeting in 1999 (see sect. 2) it was decided to set up an international study group (58 members) with the task to work out a first proposal. This modest proposal SESAME I was presented in October 1999 in the “Green Book” with the concept to upgrade the energy of BESSY I from 0.8 GeV to 1 GeV by increasing the circumference from 62 m to 100.8 m and by modifying the bending magnets (emittance 50 nm·rad). A round building like the one of BESSY I was planned, able to house 10 beamlines. The total cost was estimated at about $40 m (machine $6 m, building and infrastructure $14 m, beamlines $17 m).

In the following years several workshops were organised in order to better determine the needs of future users. It became obvious that a higher energy was required since SESAME was supposed to enable competitive research instead of being just a machine for training [4]. In April 2002 a “White Book” [5], SESAME II, was presented which had been worked out under the guidance of the first Technical Director of SESAME, Dieter Einfeld, supported by many international experts. This proposal implied a radical
change, not only in the technical concept of the machine but in the project as a whole. A completely new main ring was planned with an energy of 2 GeV and a circumference of 120 m. Obviously this required a greater building and, in order to save funds and time, it was decided to copy the square building of the ANKA machine at Karlsruhe. The whole BESSY I system consisting of an electron source, microtron with an energy of 22.5 MeV and a 0.8 GeV synchrotron was to become the injector and pre-accelerator system.

The cost estimate for the new main ring was about $14 millions. Since it seemed unlikely to obtain such an amount from the Members, a somewhat unusual finance policy was established. It was hoped that from existing laboratories some individual components, either surplus or outdated, could be obtained as gifts. In addition a request for the main ring was submitted to the European Union.

Following discussions in the Technical and Scientific Advisory Committees which in the meantime had been established by the Interim Council and taking into account the suggestions of the EU evaluation (see sect. 8.2) a conceptual design report was presented in May 2003, the “Yellow Book” or SESAME III [6]. The energy was increased to 2.5 GeV with a possible first stage at 2 GeV, without increasing the circumference of the main ring. This was achieved by installing pole face windings for the bending magnets thereby also changing the vertical focussing.

Further improvements were introduced by each of the Technical Directors following Einfeld, i.e. G. Vignola (from Frascati), A. Nadji (from Orsay) and E. Huttel (from Karlsruhe). This “upgraded Yellow Book” or SESAME IV with extensive Addenda provided the basis for the final design. Changes to building, placing the machine asymmetrical into the building (fig. 19) and improving the beam optics allowed to lengthen the circumference to 133.2 m [7]. This offered not only about 50 m straight sections for insertions
but also enabled beamlines with lengths up to 33 m. By introducing special quadrupole and sextupole magnets for better focusing, an emittance of 17 nm rad was expected. The accelerating RF cavities provided graciously by other laboratories (e.g. by ELETTRA at Trieste) are of conventional design. However, instead of klystrons they are powered by solid state amplifiers developed by SOLEIL which are considerably more reliable than klystrons.

Fig. 20. – The upgraded BESSY booster synchrotron installed in the SESAME hall. With the new roof. In front H. Winick and Prince Ghazi.

Fig. 21. – The magnets of the main ring after installation. The inset lists all parts of the main ring.
Since the building had been finished on schedule, the installation of the BESSY components could start and the microtron and the booster synchrotron were practically ready to start operation at the end of 2013 when the roof disaster occurred (fig. 20). However, the construction of the main ring was delayed because of the financing problems (see secs. 8.2 and 8.3). Many of the components for the main ring could be acquired with the help of other SR laboratories, partly using old equipment partly building new components. The magnets of the main ring (fig. 21) were constructed under the control of CERN and the main ring was installed in a record time during 2016. A first beam started circulating at the beginning of 2017.

The technical development of the SESAME synchrotron was greatly helped by an international Technical Advisory Committee, first chaired by Costas Papanicolas (Cyprus) and presently by A. Wrulich (Switzerland).

With these parameters SESAME is expected to become a fully competitive facility of the 3rd generation comparable to those in France (SOLEIL), the Canadian Light Source or the Taiwan Photon Source but for some time it will be the only such facility in the region [8].

8.2. The EU evaluation. – Because of the decision to use the BESSY components only as an injector system and to build a new main ring for SESAME, it became necessary to find new sources of financing. The chances to obtain investment funds from the Members seemed extremely small. One possibility was the European Commission which was sponsoring a Neighbourhood Programme for projects outside Europe. However, it was not clear to which programme one could apply and several informal contacts were established in 1999 and 2000 at high level such as between UNESCO DG F. Mayor and EU President R. Prodi, between UNESCO ADG Iaccarino and Commissioner Nielsen (Humanitarian Aid) and by ADG G. Glaser and Commissioner Ch. Patten (External relations). The outcome was encouraging and support of SESAME seemed indeed possible, but only through the MEDA programme, the principle EU instrument for Mediterranean partnership. A total of EUR 3.4 billions, were available for this programme for 3 years. We were warned however, that 90% of this budget went to bilateral cooperation and only 10% for regional cooperation and in both cases mainly for infrastructure like roads or water projects.

Raither from UNESCO and Schopper met at Brussel Peter Zangl (Director, Middle East, South Mediterranean Directorate) and Renate Hahlen who explained the conditions and formalities for a formal proposal and they proposed to submit a demand and a formal request to Commissioner Ch. Patten. This was done on 23 July 2001 asking for $10 millions to build a new main ring. This request was supported by the German and French Ministers of Research, E. Buhlman and R.-G. Schwartzenberg. Later also Commissioner for Research Ph. Busquin gave its full support. These contacts created a lot of optimism—too soon as it turned out!

In October 2001 Schopper was informed by Anthony Cary (chef de cabinet of Commissioner Patten) that an independent evaluation by a panel of international experts is needed. A. Knott (Director of Europe Aid Cooperation)(6) attended the IC meeting in December 2001 and explained that the setting-up of an evaluation panel had to go

(6) Later other delegates from EU, e.g. Mr. Moran, participated in the IC meetings. EU refused to become Observer at that time and only recently when the contacts where transferred to the Commissioner for Research the EU became Observer
through a public competitive adjudication process. After several months the contract for a “Techno-Economic Feasibility Study” had been adjudicated to the winning group of experts under the guidance of Prof. Guy Le Lay (University Marseille) with the members M. C. Asensio Arino, P. F. Lindley and M. Ropert. After several meetings with SESAME representatives they provided a very detailed report concerning many issues including technical and scientific aspects of the facility, staffing and training, the possible users’ community, but also the formal frame and managerial aspects. At the time when the report [9] was submitted to EU (18 September 2002) many of these questions were still open since SESAME had not yet been formally approved by UNESCO. Nevertheless the report was quite positive with the final conclusion: “All the experts are very positive of the overall concept behind the SESAME project and envisage that it would effectively stimulate scientific activity and cooperation in the Middle East as well as helping to alleviate political tension and promote peace in the region. The proviso is, indeed that it is really opened to all qualified scientists in the region and elsewhere, without any racial or religious discrimination, and that equal opportunity is given to males and females. Prof. Herwig Schopper, the President of the SESAME Interim Council, has faced, with much ingenuity, since the beginning, a very challenging mission, while Dr. Dieter Einfeld, the Technical Director, has performed in a very short time, and with just very limited resources an extensive and valuable work on the definition of the machine and infrastructure, even if more work is still needed to optimize the overall design […] To conclude, the experts have made firm, but positive, recommendations, with the aim to ensure the effective accomplishment of this ambitious project and the success of the SESAME Centre.”

After the report had been submitted, Schopper received from EU a copy in printed form. Asked for a digitised version to distribute it, the EU answered that they did not have such a file. Putting the same question to the chairman of the evaluation panel he promised immediately to send a digitized version of the report. However, a few days later he informed Schopper that he was not allowed to send his file since the report had been formally submitted to EU and thus it had become its intellectual property and only they were allowed to distribute it. So the final report including many annexes had to be scanned, all together more than 100 pages. Bureaucracy is certainly not a friend of scientific projects!

SESAME submitted in August 2003 several documents to EU answering all the questions raised by the evaluation panel clarifying the political, technical, scientific and financial issues. Various attempts to have a follow-up failed. Finally Schopper received letters from Commissioner Ch. Patten and R. Weber (Director of Europe Aid Cooperation) simply stating “that the Commission is not in a position at this stage to provide Community funding to SESAME”.

Only after Schopper’s insistence to organise a meeting to discuss the submitted documents, a meeting was arranged. However, this EU Commission was not accustomed to negotiate with scientists and insisted to deal only with the Jordanian government. Hence the invitation was sent to the Jordanian Ambassador at Brussel who had the invitation translated into Arab, sent it to Amman where it was retranslated into English and forwarded finally to Schopper. When he saw the names of the participants supposed to be met at Brussels they all seemed unfamiliar. However, when the meeting started it turned out that the SESAME representatives knew most of the EU people, but the translation into Arab and the retranslation into English had completely corrupted the names.

The meeting on 10 March 2004 in Brussel was attended by J.-L-Picque (DG Research), J.N. Del Barrio Manas (Europe Aid Cooperation), M.-A. Balbinot (Principal
Administrator Programme Egypt and Jordan, Le Al-Hadid (Jordanian Embassy) and from SESAME H. Schopper, G. Vignola, S. Hasnain and R. Saraf. One important point of disagreement concerned the chosen energy of SESAME. It was claimed that a competitive facility needed a higher energy. After a lively discussion during several hours a compromise was reached: the machine should start at 2 GeV, but everything should be foreseen that by adding accelerating RF cavities 2.5 GeV should be available at a later stage. This implied an increase of the cost and $12 millions were recommended instead of the originally requested $10 millions. Otherwise all other questions were considered to have been fully answered by the submitted documents and the explanations given during the meeting. After the formal meeting Mrs. Balbinot mentioned that the requested money was no problem, but the responsible directorate did not know which programme to use—a bilateral programme with Jordan or a regional programme. EU preferred the bilateral programme and from then on all negotiations went via the Jordanian Embassy and the Jordanian Ministry for Planning. As a first step the EU was prepared to give a grant of EUR 1.2 millions within the bilateral programme for Jordan provided Jordan would ask for it. A special request had to be prepared by Jordan and thanks to the favourable attitude of the Jordanian authorities and the engagement of Kh. Toukan this sum was made available for SESAME.

Concerning the financing of the main ring the situation remained, however, unchanged in spite of many interventions from various sides. Without a decision from EU the project was delayed and even put in danger since without the main ring the whole facility was useless. The SESAME Council addressed a declaration in December 2004 to Mrs. B. Ferrero-Waldner, Commissioner for External relations and Neighbourhood Policy, who had followed Commissioner Patten, without receiving much reaction. Since time was running, the SESAME Council asked its President to organise a letter of support signed by Nobel laureates of whom 45 had visited SESAME (fig. 22). Schopper managed to collect 27 signatures and sent the letter stating “urged the EU [...] to provide the critically needed investment funds for the main part of the machine” to Ferrero-Waldner.

There was no answer, not even a polite letter confirming the receipt. It became known that Ferrero-Waldner intended to visit Jordan and wished to meet King Abdullah II. It was arranged that the King would ask her about that letter, which happened. Big
surprise—she had never seen the letter. Apparently her cabinet had held it back. As a result she wrote in May 2008 to Schopper affirming that the project was considered as very interesting but no solution as to the choice of the programme had yet been found. Ambassador P. Renauld, Head of EU delegation at Amman, was charged to find a possible solution. Although he was very understanding and really tried to help, he could not solve this question. Money was not the problem, but finding an appropriate programme—regional or bilateral—has delayed the project by several years and put it even in danger of a complete failure.

8.3. EU-CERN Collaboration. – Finally CERN came in and a way out of the stalemate was found. In negotiations started by DG Rolf Heuer between CERN and the Commissioner for Research and Innovation, Carlos Moedas, a new way of collaboration was discovered. Funds were approved for CERN with the mandate to use them for the construction of the magnets of the SESAME main ring. In total about $5 millions were approved. CERN was in addition prepared to organise the construction of the magnets and to train the SESAME staff responsible for the magnets. Now the relations between EU and SESAME including CERN have completely changed to the positive side and EU became Observer at SESAME.

9. – The finance strategy

All the usual methods to finance a new project like SESAME would not have worked under the conditions in the region. The financial power and the governmental structures of the Members differed too much and changed during the establishment of SESAME with the political situation. To simply share the total cost of SESAME between the Members was not a possible solution. Therefore the strategy proposed and approved by the Interim Council was to financing the various elements of the projects in the following way:

– the site preparation, building and infrastructure (roads, electricity and water) by host state,
– the annual operating budget (salaries, various consumables, etc.) by Members
– the technical components of the facility: injection system gift from Germany, main ring financed by EU and some contributions in kind by Observers
– beam lines obtained as gifts from other laboratories or specific projects of individual Members
– training of technicians and scientists by extra-budgetary contributions from IAEA Vienna, USA and other donors.

This was a rather complicated and risky scheme, but unavoidable taking into account the special situation in the region. In particular no clear separation between operation and investment was foreseen, an advantage taken over from CERN which provides a remarkable flexibility in coping with financial difficulties as they arise.

9.1. The annual operating budget. – The first approach was to accept the CERN system where the total yearly budget is decided by Council and is shared automatically between Members according to their GNP with the additional condition that a maximum amount for the yearly contribution is fixed in order to avoid that one country would dominate. After long discussion in the Finance Committee, which had been set up with one government representative for each country, it was decided to fix a maximum and
a minimum contribution. But the strict distribution according to the GNP was not acceptable. After discussing various other financial indicators like the GNP/capita or taking into account the scientific strength of the countries it was decided in the spirit of a reasonable cooperation and mutual trust that the countries would be grouped into 4 categories, the riches paying the maximum amount, a category for the minimum amount and two others in between. The minimum amount was applied to Palestine because of its special political position.

Although most states tried to follow this agreement, there were two major problems. Naturally the SESAME budget had to increase continuously from zero to an estimated total operation budget of about $6 millions per year when operation would start. To convince finance ministries of yearly budget increases by 20 to 30%, however, is extremely difficult since absolute budget numbers seem to be less important than relative changes. In addition unforeseeable events hit some states, like political or financial crises, with the result that some contributions could not be paid at all or were paid only partially. The hope is that the accumulated debts will be provided in the future to finance some missing elements or upgrades.

Since the main part of the operations budget is needed for salaries, the absence of full contributions had the result of an understaffing. This was partially compensated by using fellows or other non-permanent employees. But unacceptable delays in the programme could only be avoided by a remarkable engagement and enthusiasm of the staff.

A great difficulty due to the very special political situation in the region arose recently in connection with electricity prices. In the past Jordan could get electricity at very favourable prices from Syria whereas presently the normal electricity prices of $375/MWh have to be paid. The cost of electricity consumption with SESAME operating at full power can easily be estimated to swallow almost the whole planned operating budget. Since an increase of the budget by such amounts seems unrealistic, a new strategy has been developed with the help of the Jordanian authorities. It is planned to install a solar power plant for about 6 MW which will be connected to the public network and will deliver any surplus power to this net. In this way SESAME will receive power even when the Sun is not shining and the average electricity prices will become acceptable. The necessary area for the solar panels has been secured and also the necessary funds are available. The detailed negotiations with the public network will be settled in the near future. Also in this case the support by the host state is essential and surpasses its original commitments. On the other hand such a solar power plant will contribute to the development of sustainable energy production in Jordan.

At present the yearly operation budget is about $4.4 millions. It will have to increase to about $5.8 millions in 3 years when the facility will be in full operation. Even the largest Members would not have to contribute more than about $600 000/year, a relatively modest contribution but a non-negligible amount for some countries with very small research budgets. To convince the Members to accept such an increase, small in absolute numbers but large in percentage, was one of the major problems to be solved by the Council President Llewellyn-Smith. He was supported in this task by the Finance Committee chaired for many years by Salman Salman (Palestine) followed by Tahir Saeed (Pakistan).

9'2. Investments. – As has been explained there was little hope that the investment for the machine itself could come from the Members. Other sources had to be found. Yet in most places it was frustrating to learn what an excellent project SESAME was, but when it came to cash contributions great obstacles appeared. Italy was a remarkable exception by making considerable funds available (see table I) in a very generous way.
Table I. – *Total cash and in-kind contributions up to October 2016 in US $ millions (without training)*.

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<tr>
<td>Immovable property (land, building, electrical power line, etc.)</td>
<td>12.77</td>
</tr>
<tr>
<td>Donation in 2002 of BESSY I components</td>
<td>~ 10∗</td>
</tr>
<tr>
<td>Equipment for the SESAME machine</td>
<td>1.85</td>
</tr>
<tr>
<td>Beamlines and beamline components donated to SESAME</td>
<td>23.3</td>
</tr>
<tr>
<td>Cash donations for construction of SESAME machine</td>
<td>3.38</td>
</tr>
<tr>
<td>Cash donations for construction of SESAME machine</td>
<td>~ 11.3∗</td>
</tr>
<tr>
<td>Cash donation from Italy</td>
<td>~ 3.48∗∗</td>
</tr>
<tr>
<td>Manpower + operational costs</td>
<td>16.88</td>
</tr>
<tr>
<td>Total</td>
<td>~ $97.96 millions</td>
</tr>
</tbody>
</table>

∗ 1 EUR = 1.3 USD.
** 1 EUR = 1.22 USD.

The situation was much more favourable when it came to contributions in kind. This was not only true for components of the machine but even more so for the acquisition of elements for the beamlines. As mentioned above the hope was from the beginning that beamlines could be obtained from other laboratories, be it because they were not needed anymore or some spare items were available. Thanks to the generousities of partner laboratories in Europe (France and UK and again Italy provided exceptional help) and the USA (SLAC in particular) the help obtained was significant, not only for beamline equipment but also accelerator components were made available.

Two visits to the USA were undertaken to explore the possibility to obtain a financial contribution from governmental institutions. The first one by Kh. Toukan and H. Schopper and the second by Ch. Llewellyn-Smith. The results were rather similar and disappointing. The State Department was very interested, appreciated the political aspects of SESAME and wanted to help. However, no big funds for scientific projects are available. Nevertheless some funds for the training programme were provided. The only department which would have sufficient funds to support a project like SEAME was the DOE. They were in principle prepared to help, but they were afraid that they would be criticised by US scientists to provide funds for SASEME at a time when the US needed more resources for SR facilities at BNL and Argonne.
The discussions with EU concerning the financing of a new main ring have been described already (sect. 8.2). Although the request for the financing of the main ring had been evaluated positively and the fund itself presented no problem, it was not possible to find an adequate programme. In the end a partial solution was found involving CERN (sect. 8.3). This had the advantage that not only the financial crisis was softened but the whole experience of CERN could be exploited, including the training of the involved SESAME staff. In total an amount of about $11 millions was contributed by the EU (table I).

When the EU contribution was still pending and the project was in extreme difficulties the Israeli Council delegate, Eliezer Rabinovici, suggested in 2010 that the big Members (Egypt, Iran, Israel, Jordan and Turkey) should each make a voluntary contribution of $5 millions. These countries agreed to the “Rabinovici initiative”, but an unexpected change of the Egyptian government and the sanctions against Iran had the consequence that these two countries could not yet fulfil their voluntary obligations. Nevertheless these voluntary contributions of $15 millions kept the project going (fig. 23). Additional help came from Italy which agreed to contribute in an extremely generous and much appreciated way funds of about $3.5 millions although being only an Observer.

As table I shows, the total cost of the facility during its construction period amounts to about $80 millions. However, this may underestimate the value of some of the components for the machine and beam lines provided by other institutes and the personnel cost of many persons who worked without pay.

10. – The scientific programme

10.1. Long-term scientific programme. – A third generation synchrotron facility like SESAME with a beam energy of 2.5 GeV and up to about 25 beamlines offers a large
number of possibilities to do research in domains which are relevant to the region. Relevant research domains with some examples are shown in fig. 24.

To assure that the facility would not become a “white elephant” i.e. not being properly used, a big effort was undertaken right from the beginning to form a user community. For this purpose a Scientific Advisory Committee, chaired by Zehra Sayers (Turkey) (fig. 25) and a Beamlines Committee, chaired by Samar Hasnain, (Pakistan and UK) and followed by Zaid Hussain (LBL), were set up. They contributed very essentially to organise the users’ community by regular user workshops in different countries. The purpose of these workshops was not only to train future users but also to determine their preferred research topics in order to develop a strategy for future beamlines. After the first beamlines had been decided upon, it was even possible to send users to other laboratories to test beamline components and even produce the first publications [10] and Master Thesis [11].
Fig. 26. – The final layout of the SESAME hall with possible beamlines. The 4 initial beamlines are indicated by boxes in colour.

Fig. 27. – Components of the X-ray beamline at installation.

10.2. Phase 1 beamlines. – Based on the discussion with the users and in the Advisory Boards a long-term strategy for future beamlines was developed. The result is shown in fig. 26. In total up to 28 beamlines could be installed in the long-term future with lengths up to 37 m. The machine has 16 straight sections, half of them with a length of 4.4 m, sufficiently long to insert wigglers or undulators.
Table II. – Phase 1 beamlines.

<table>
<thead>
<tr>
<th>Beamline</th>
<th>Energy range</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray Absorption Fine Structure/</td>
<td>4–30 keV</td>
<td>Bending magnet</td>
</tr>
<tr>
<td>X-ray Fluorescence Spectroscopy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(XAFS/XRF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrared spectromicroscopy (IR)</td>
<td>0.01–1 eV</td>
<td>Bending magnet</td>
</tr>
<tr>
<td>Materials Science (MS)</td>
<td>3–25 keV</td>
<td>Multi-pole wiggler</td>
</tr>
<tr>
<td>Macromolecular Crystallography (MX)</td>
<td>4–14 keV</td>
<td>Undulator</td>
</tr>
<tr>
<td>Small Angle and Wide Angle X-Ray</td>
<td>8–12 keV</td>
<td>Bending magnet</td>
</tr>
<tr>
<td>Scattering (SAXS/WAXS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Ultraviolet spectroscopy (EUV)</td>
<td>10–200 eV</td>
<td>Bending magnet</td>
</tr>
<tr>
<td>Soft X-ray/Vacuum Ultra-Violet (VUV)</td>
<td>0.05–2 keV</td>
<td>Elliptically polarized undulator</td>
</tr>
</tbody>
</table>

For the first period after the start-up of SESAME seven beamlines shown in table II are foreseen to be installed according to the wishes of the users.

These Phase 1 beamlines can be used for the following examples of research:

The X-ray Fluorescence and Absorption beamline will be used for non-invasive measurements of absorption edge and fluorescence emission spectra. Elemental composition and physical properties of inorganic and biological materials can be determined at μm scale. These are very flexible techniques used in materials science, biology and cultural heritage (fig. 27).

The Infrared Microspectroscopy beamline will be the basis for measurements of vibrations of bonds that absorb in the IR region which is a powerful tool for identifying/mapping components of cells/tissues with different chemical properties, e.g. lipids, carbohydrates, proteins and nucleic acids. This offers possibilities for time-resolved imaging of living cells.

The Materials Science beamline will enable studies of ordered and disordered/amorphous material on the atomic scale, of the evolution of nano-scale structures and materials in extreme conditions of pressure and temperature, developing and characterizing new smart materials.

The Protein Crystallography beamline, an important tool for structural molecular biology, provides a basic understanding of biological mechanisms at atomic level and gives insight for developing new drugs and therapies(7).

The Small and Wide Angle X-ray Scattering beamline will allow measurement of diffuse scattering from large macromolecular assemblies and non-crystalline systems. It provides shape information and allows for time-resolved measurements to monitor structural changes during protein-protein interactions. Various applications in molecular biology and materials science can be expected.

The Extreme Ultraviolet beamline is a tool for atomic and molecular physics. It will allow to study the behaviour of atmospheric gases and the characterization of the electrical and mechanical properties of materials, surfaces and interfaces.

(7) Thanks to a special contribution by the Jordanian Scientific Research Support Fund of 2.1 million USD a vacuum undulator is planned for this beam line.
The Soft X-ray Vacuum Ultraviolet beamline will also permit the study of atomic, molecular and condensed matter physics, in particular surface science like the behaviour of catalysts and how they can be improved.

The two beamlines, for IR and XAFS/XRF, will be ready in spring 2017 and a third, for material science, somewhat later. Of course, those beamlines will first be used by those scientists and laboratories who contributed to establish them.

SESAME beamlines are in principle open to all users. On a trial basis a “Call 0” for public beam time was opened on 15 December 2016 with a deadline for proposals on 15 March 2017. A Proposal Review Committee with distinguished international experts was established to evaluate these proposals.

In addition it is hoped that new beamlines will be proposed. In general a somewhat demanding beamline might cost between $2 and 3 millions. They could be financed by SESAME or funded by an outside group as it happened already.

10.3. Support of users. – It should be mentioned that SESAME is becoming a full partner of three EU H2020 projects together with several European Research Infrastructures. For example the VI SEEM is a 3 years project to create a Virtual Research Environment (VRE) in Southeast Europe and the Eastern Mediterranean (SEEM). If approved, it will be possible for SESAME to support travel expenses of European users accessing SESAME. CALIPSO PLUS is a proposal to support Trans-National Access to SR laboratories with the possibility for SESAME to support travel expenses of European users.

The “Open SESAME” proposal has been submitted to the EU and was approved with a budget of about EUR 2 millions. It will provide SESAME with an excellent opportunity to train its staff and perspective users.

The SESAME infrared laboratory is recognized as an Affiliated Centre of ICTP, Trieste, and equipment and fellowships have already been approved in collaboration with the Palestinian Authority for two activities, “Different Drugs Effects on the Human Skin Tissue” and “Activity of a combination of Doxorubicin/Quercetin on Breast Cancer Cell Lines”. This beamline is particularly promising for IR micro-spectroscopy.

The data produced by the experiments will be made available to the home institutes of the users by good network connections. An agreement with the Cyprus Institute at Nicosia foresees that the powerful computing capacity at this institute can be used for the analysis of SESAME data, which, in particular for biological investigations, might be quite demanding.

In summary it seems not too optimistic to expect that the scientific activities at SESAME will start vigorously when the first beams become available in spring 2017.

11. – Training programme

The training of scientists, engineers and technicians was considered to be important from the beginning in order to be able to recruit staff members from Members and to build up a users’ community. To help to organise the formation and training an international Training Committee (chaired by Reza Mansuri followed by J. Rahighi, both from Iran) was established. Recently an Interim Users’ Executive Committee representing scientists from all SESAME members was launched.

11.1. Training of individual experts. – The most urgent need at the beginning was to train accelerator experts who would help to construct the machine. For this purpose 20
scientists and engineers were selected among a large sample of applicants from Members and sent to European and US laboratories for one or two years. This first attempt was not a great success for SESAME since the selected young people turned out to be so good that most of them were offered jobs at the accepting laboratories. If not for SESAME it was nevertheless a benefit for the home countries since later most of them returned home and some even came to SESAME.

A training scheme for individual scientists was continued by granting fellowships for visits of longer or shorter times to synchrotron laboratories in Brazil, France, Germany, Italy, Japan, Portugal, Spain, Sweden, Switzerland, in Taipei, UK and USA. More than 300 scientists have been supported in this way. The funding of these training activities came from various sources outside the SESAME budget. A major part of the funding (more than $1 million) came from the IAEA in Vienna. In early contacts with Deputy-DG W. Burkart responsible for training at IAEA led to close relations which were strengthened by SESAME Council meetings at IAEA in 2007 and 2010. But other international organisations like UNESCO, ICTP, IUPAP and EPS or national societies like SIF, DPG, APS, SFP, JSPS and IOP contributed also. The training programme was also supported by individual states e.g. the US State Department and DoE and EU and some SESAME Members made special contributions. But even some private companies and foundations helped in the formation of scientists from the MENA region, e.g. Gen-tech, Ox Diffraction, PAN analytical, Jordanian Phosphate Mining co. and Canon and Lounsbery Foundations.

To organise such a complicated training programme put a heavy load on the SESAME administration and on the Training Committee.

11.2. Workshops and users’ meetings. – Another important task was to create a users’ community which would provide early inputs for the planning of beamlines and guarantee an efficient use of the facility right from the beginning. For this purpose users’ meetings and special workshops and schools were organised even before the formal foundation of SESAME.

Indeed the first users’ meeting took place at Amman in 2002 and was financed by the Japanese Society for the Promotion of Science. It was attended already by about 50 scientists from the MENA region. This number increased to several hundreds in later users’ meetings. Many users also met at the SESAME site at the occasion of the ground breaking ceremony (fig. 28). It gave excellent evidence how SESAME can help to foster better understanding between people from different countries. For example contacts between Israelis and Iranians were extremely difficult in those times. The second users’ meeting took place at Isfahan, Iran (fig. 29). These meetings provided general information about the progress of the SESAME project and were organised once every year (except for 2010) until 2016.

Workshops and schools for future SESAME users took place since 2000, individually or sometimes associated with Users’ Meetings and they covered specialized topics, like materials science, structural biology and bioinformatics, IR spectroscopy, XAFS/XRF.

On 3 December 2016 a SESAME Users Group has been established (chair Ozgul Kurtlus Ozturk, Turkey) which has created a Cultural Heritage Group initiated with 30 scientists from different countries. In addition a SESAME User Office [12] was set up with the main task to help users to learn how to apply for beam time.
Fig. 28. – Users’ meeting organised at the occasion of ground breaking. At the centre G.-A. Voss (with black glasses), to his immediate left Deutsch (Israel), then Mansuri (Iran), third to his right Burkart (IAEA).

Fig. 29. – Second SESAME users’ meeting at Isfahan, October 2003.
12. – Perspectives

SESAME is now passing from the stage of construction to the phase of exploitation. This will be marked by a formal inauguration ceremony in May 2017.

But even during the construction phase the Members could already enjoy some benefits. This concerns above all the training. A number of technically oriented scientists and engineers from the Members participated actively in the design and construction of the facility and this will provide a valuable stock of professionals when some of the Members will build their own SR facilities. Some concrete plans exist already in several countries and in this way SESAME will contribute as a pilot project to the long-term scientific and technical development of the region.

In addition more than 300 scientists from various scientific fields received training in existing laboratories and they produced even some scientific publications, among them 5 Master Thesis. Also the first indication of a reversal of brain drain becomes visible and this will hopefully become an important outcome of SESAME once the machine will be in full operation.

From the technical aspect one might hope that in the not too distant future the present injector system can be replaced by a linear accelerator which would increase the available light intensities and make the machine even more interesting. For the convenience of the users a larger guest house and a cafeteria are planned. Together with an auditorium this will contribute to SESAME becoming a general meeting place for the whole region.

Several other countries have expressed interest to join SESAME and this might happen in particular if the present political situation in the region improves.

SESAME has already fulfilled one of its promises—it has shown that people from different countries with various traditions, conflicting political systems and diverse mentalities can peacefully work together if a common competitive objective is guiding them. It is always healthier if people talk to each other instead of being hostile and if they talk about science and technical issues they will build up confidence among themselves to solve other problems. A contribution to peace!

* * *

In this article countless material was used from official and internal SESAME reports and private information and various other sources. The names of some of the people who have contributed to the advances of SESAME are mentioned in this article but an even larger number could not be quoted. The author would like to thank all of them not only for providing the information but also for a very pleasant cooperation during many years. This article expresses the views of the author.

REFERENCES

[1] Some of the information quoted in this article and more (e.g. details about the staff) can be found on the official SESAME Websites: http://www.sesame.org.jo/sesame/ and http://www.sesame.org.jo/sesame/about-us/what-is-sesame.html.

Since some questions as to the splitting of the total amount of $600,000 arose, one might consult UNESCO Exec. Board, 162 EX/49 Add, item 11.


For a list of all SR sources in the different regions of the world see [http://www.lightsources.org/regions](http://www.lightsources.org/regions).


Nirmeen ElMadanay, “Antiproliferative activity of the combination of doxorubicin/quercetin on breast cancer cell lines: possible role of changes in oxidative stress level"
Masters Thesis, Clinical Pharmacy, The University of Jordan (2015); Worood Shadeed, “Visualization of Different Drugs Effects on the Human Skin Tissue: An Infrared Microspectroscopic Study”, Masters Thesis, Department of Physics, Bir Zeit University (2015); Riyad Jaber, “XAFS: a synchrotron based technique for analyzing soils samples, from Zarqa River and the Industrial Sahab City areas in Jordan”, Masters Thesis, Department of Civil Engineering, Jordan University (on going); Adel Beshir, “Adsorption and Mobility of heavy metals in soil systems from Hebron, Jericho and Qalqilia in Palestine (west bank)”, Masters Thesis, Department of Physics, Al-Quds University, Hebron; Safwan Shalaldeh, “Simulating zircon structure around Pb as result of storing non-conventional wastes”, Masters Thesis, Department of Physics, Al-Quds University, Hebron.