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MEASUREMENT OF LASER INDUCED IONIZATION IN AN
ARGON-ETHANE GAS MIXTURE

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ABSTRACT

A nitrogen laser was used as the source of ionization of an Argon-Ethane gas mixture, and the degree of ionization was investigated. The ionizability was found to be a quadratic function₂ of the laser power-density up to a power of about 60 kW/mm², above which it appears to saturate.

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The use of focussed nitrogen laser shots as an ionizing source of an argon-ethane gas mixture is one of the most promising calibration methods for drift chambers.

In principle, a laser beam is an easily controlled tool, both in space and in time.

The main problem in designing laser calibration set-ups was that the behaviour of the ionization intensity as a function of laser power density was still unknown. Some authors⁽¹⁾ have found a linear law, others⁽²⁾ quadratic, but no quantitative determination has been made until now.

The physical process that allows nitrogen laser photons (3.68 eV) to ionize either argon atoms (1st excited level at 11.5 eV and ionizing potential at 15.75 eV) or ethane molecules (start of absorption bands at about 7.75 eV) is not yet understood and most of the authors attribute the ionizability to impurities.

H. Anderhub et al.⁽⁴⁾ improved dramatically the ionizability by adding nickelocene vapour (ionization energy 6.5 eV) to their gases. Sadoulet et al.^(2,3) added diethylaniline. Theoretical calculations⁽⁵⁾ require only microscopic concentrations (10^{-10} ./ 10^{-15}) of easily ionizable impurities to explain the observed signals with double photon ionization process.

Even if we cannot exclude the presence of tiny amounts of impurities in our gases it appears very improbable that we had, over more than one year of tests, a steady concentration of a peculiar, easily ionizable agent that produced always the same gas ionizability.

The present work was designed to determine the law relating the ionization intensity to the laser power-density, disregarding the underlying physical process.

1. EXPERIMENTAL SET-UP

A block diagram of our experimental set-up is shown in Fig. 1.

We used a commercial nitrogen multimode laser P.R.A. LN 100, 300 ps pulse duration, 50 μ J/pulse energy, with a rectangular beam shape of 1.75 by 2.7 mm at the laser and 5.5 by 10 mrad divergence. Owing to the multimode characteristic of this laser, the power distribution in the spot is almost flat.

A beam splitter close to the laser gave a timing flash to a fast photodiode (less than 1 ns risetime) for synchronizing the data acquisition electronics.

A set of calibrated aluminium attenuators was placed after the beam splitter to attenuate the beam by a known amount. The transmission of these filters was given by the manufacturer to a precision of 2 % at nitrogen laser wavelength.

A slit collimator at 1.5 m from the laser let in only the central part of the laser spot to obtain a clean, sharp-edge beam with uniform power-density.

A 200 mm focal-length lens after the collimator focussed the beam in the active volume of the drift chamber. The dimensions of the caustic measured on photographs of the beam in the focus region were $(0.175 \pm 0.025 \times 0.45 \pm 0.1) = 0.08 \pm 0.02 \text{ mm}^2$ over about 10 mm depth, which was more than the thickness of the active volume of our drift cells.

The shot energy of the not attenuated beam, measured after the focussing lens with a Molectron joule-meter, was $10 \pm 0.5 \text{ } \mu\text{J}$. The shot-to-shot 5 % power jitter of our laser proved not to be critical for our experiment.

The drift chamber we used for this test was one of the UA1 luminosity chambers, built by a collaboration of the SPS/EA Group and University of California, Riverside. The drift field was 900 V/cm in a 50 % argon, 50 % ethane gas mixture which was fluxed through the chamber at the rate of 0.5 volumes per hour to assure gas purity.

Each chamber had twelve separate cells of 21 mm drift length and 6 mm thickness. (The borders of the drift region for each cell were defined by two vertical planes of field wires, 6 mm apart.)

In each plane the field wires occurred at 2 mm intervals and we were able to fire the laser precisely inbetween them. It was very important not to hit the wires to avoid generating a large number of photoelectrons on the wire itself.

We fired our laser 10 mm away from the sense wire, half-way through the cell. In order to reach the active volume of the cell, the beam had to cross the mylar window of the chamber (transmission 0.75 ± 0.02 at this wavelength) and a ground grid (50 micron wire diameter, 0.5 mm spacing). As the grid was far away from the focus it uniformly attenuated the beam and had a transmission of 0.8.

Considering all these effects we had in the focal region up to 6 ± 0.5 μ J/pulse. Our 6 μ J/pulses were able to induce large signals in the chamber. We could obtain

650 ± 30 mV laser generated signals to be compared to the 600 ± 50 mV of a Fe55 radioactive source.

The signal induced on the two ends of the sense wire were read by two linear amplifiers designed for charge division reading. These amplifiers are linear over all the explored range of signals.

2. DATA ACQUISITION

The signals of the two linear amplifiers were integrated on a gated ADC 2249A. The gate (80 ns) was obtained by shaping and delaying the timing photodiode signal. The timing photodiode pulse-height gave us a monitor of the laser shot-to-shot energy jitter. We stored on disk 2000 events for each attenuation value, each event including the timing photodiode pulse-height and the two ADC counts. Our results are summarized in Table 1.

With the combinations of our four attenuators (transmission 0.70, 0.447, 0.380, 0.0977) we were able to attenuate the shot-energy down to 0.07 μ J in 16 steps.

Two measurements made without attenuation at the beginning and at the end of our run agreed well within the errors.

The ADC offset was measured by blocking the laser beam after the timing photodiode. The ADC counts were summed and averaged offline. The ionization intensities were taken as proportional to the number of the ADC counts minus the offset.

3. RESULTS

A logarithmic plot of ionization intensity versus laser-shot energy density (Fig. 2) shows that the ionization is a quadratic function up to energy densities of $20 \mu\text{J}/\text{mm}^2$ and becomes linear for energy density larger than $20 \mu\text{J}/\text{mm}^2$. (A linear fit on the logarithmic plot gives an exponent of 2.15 ± 0.1 while for higher energies the obtained exponent is 1.12 ± 0.02 .) If the pulse duration (300 ps, as given by the laser specifications) is taken into account, saturation is reached at about $60 \text{ kW}/\text{mm}^2$.

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T A B L E 1

Filter Transm.	Drift Chamber Signal Pulse-Height ADC Counts	Total Laser Energy 26 Counts/ μ J	Ionization Intensity ADC Counts	Attenuated Shot-Energy 26 Counts/ μ J
0.0	7.67 ± 0.03	155.0	-	0.0
1.0	1244.0 ± 1.7	155.9	1237	155.9
1.0	1218.0 ± 1.5	152.5	1210	152.5
0.7	884.0 ± 1.3	152.7	876	106.9
0.447	534.0 ± 1.1	153.3	526	68.2
0.380	391.7 ± 1.1	153.5	384	58.3
0.313	352.4 ± 1.0	152.2	345.7	47.6
0.266	157.6 ± 2.2	153.7	149.9	40.8
0.170	116.6 ± 0.69	153.5	108.9	26.1
0.0977	34.65 ± 0.37	153.2	26.9	15.0
0.0682	21.76 ± 0.27	153.7	14.1	10.5
0.0682	21.31 ± 0.27	153.8	13.6	10.5
0.0437	13.27 ± 0.16	153.7	5.6	6.7
0.0371	11.04 ± 0.12	155.3	3.38	5.8
0.0306	10.51 ± 0.11	153.8	2.81	4.7
0.0260	9.54 ± 0.09	155.2	1.87	4.03
0.0166	8.36 ± 0.06	155.3	0.69	2.58
0.0116	7.98 ± 0.05	156.0	0.31	1.81

The error on total laser energy and attenuated shot-energy is 5 %.

BM: BEAM SPLITTER
 FF: FILTERS
 C: COLLIMATOR
 L: FOCUSSING LENS
 DC: DRIFT CHAMBER

MW: MYLAR WINDOW
 GG: GROUND GRID
 FW: FIELD WIRES
 SW: SENSE WIRE
 TPD: TIMING PHOTO DIODE

Fig.1

Fig.2