M11.3.1: Requirements for electron beam diagnostics

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WP11: Assessment of Novel Accelerator Concepts

Report 1
Report on specification of the electron beam parameter suitable for emittance measurements

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1. Introduction

The all optical external injection scheme that we will use with two colliding laser pulses allows a way to stabilize the injection of electrons into the plasma wave, and to easily tune the energy of the output beam by changing the longitudinal position of the injection. The charge and relative energy spread are also controllable by tuning parameters such as the injection intensity and its polarization. We report here on the control of the e-beam parameters, on the e-beam parameters that will be used for the conception and design of the emittance meter and on the experimental arrangement on which emittance measurement experiments will be achieved.

2. Experimental conditions and results

Experiment conducted in the LOA “Salle Jaune”, with a Ti:Sa laser system that delivers two ultrashort 30 fs linearly polarized pulses. The pump pulse is focused to intensities up to \( I_0 = 4.6 \times 10^{18} \text{ W.cm}^{-2} \), which corresponds to a normalized amplitude of \( a_0 = 1.5 \). The injection pulse is focused with intensities up to \( I_1 = 4 \times 10^{17} \text{ W.cm}^{-2} \), for which \( a_1 = 0.4 \). A supersonic helium gas jet, after ionization by the front of the laser pulses, provides the plasma medium. For the purpose of emittance measurement, the geometry used for this experiment departs from the collinear one used in previous colliding pulse experiments: 176° instead of 180°. It offers several advantages: (i) it minimizes the risk of damaging the laser system by reducing the laser feedback to less than 1 mJ (ii) the electron beam can be extracted and diagnosed more easily because there are no optics in its path. The electron beam is measured with a spectrometer consisting of a dipole magnet (1.1 T over 10 cm) and a LANEX phosphor screen. It gives access to energy distribution, charge and angular distribution of the electron beam [16]. A half-wave plate followed by a polarizer, enables us to reduce the injection pulse energy before compression. A second half-wave plate enables us to rotate the polarization of the injection pulse.

On figure 1 we report on typical spectra obtained with the 3 mm nozzle, density \( n_e = 5.7 \times 10^{18} \text{ cm}^{-3} \) and collision position \( z_{\text{coll}} = -400 \mu\text{m} \) (the z axis is oriented in the direction of the pump pulse with origin in the center of the gas jet).
External injection provides a way to dramatically stabilize the injection process, and thus the production of a quasi-monoenergetic beam. On figure 2, a data set of 28 consecutive shots is reported showing a very stable beam in energy $E = 206 \pm 10$ MeV (5% rms fluctuation) with measured full width half max (FWHM) energy spread $\Delta E = 14 \pm 3$ MeV (20% rms fluctuation) (limited by the resolution of the spectrometer), FWHM divergence $\theta = 4.5 \pm 1.6$ mrad (36% rms fluctuation) and peak charge $Q_{pk} = 13 \pm 4$ pC (30% rms fluctuation).

Figure 1: Typical spectra. Left: raw data, Right: Deconvolved spectra

Figure 2: 28 consecutives shots showing the unique reproducibility of a quasi monoenergetic electron beam achieved in colliding laser pulses regime.

The experimental set-up with the corresponding photo is shown on Figure 3.
We will try to explore a geometry which will allow the have larger access to the electron beam closer to the gas jet. The experimental set up is shown on figure 4. If stable and good quality electron beam is achieved in 2009 with this more open geometry we will select for the emittance measurements.

The resolution of the electron spectrometer that we have used in the presented results was limited to 5% at 200 MeV. Recent experiments have been performed in collaboration with LLR with a 0.8% relative energy resolution spectrometer and have shown that at 200 MeV the relative energy spread was of only 1% FWHM. Such resolution was obtained using a complete apparatus composed by three quadrupoles used to focus the e-beam on the scintillator screen located after the dipole. We do not plan to reinstall this high-resolution spectrometer for the emittance measurement.
3. Conclusion

In conclusion, the table 1 resumes the parameters of the proposed electron beam that we could deliver for the emittance measurements.

<table>
<thead>
<tr>
<th>Energy</th>
<th>Charge</th>
<th>DE</th>
<th>Expected duration</th>
<th>Divergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>206 ± 10 MeV</td>
<td>13 ± 4 pC</td>
<td>ΔE = 14 ± 3 MeV</td>
<td>5-10fs</td>
<td>4.5 ±1.6 mrad</td>
</tr>
</tbody>
</table>

Table 1: summary of the electron beam parameters