Quasi monoenergetic electrons from shockwave injection

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Quasi monoenergetic eletrons

It has been shown that injection in Laser Wakefiel Acceleration (LWFA) can be stimulated with density gradients of the plasma medium. As shown in [1] such a gradient can be introduced by placing a sharp edge into the flow of a super sonic nozzle (Fig. 4(b)). Energy spreads of the accelerated electrons of 3-5 MeV have been presented in the first experiment with maximum electron energies of 25 MeV. It was showen that the absolute energy spread does not increase with further acceleration [3]. At a 150 MeV the absolute energy spread remained at 3-5 MeV. As predicted in [2] we were able to reach electron beams with less than 1% energy spread (FWHM), when we accellerated shockwave injected beams to energies of 290 MeV.

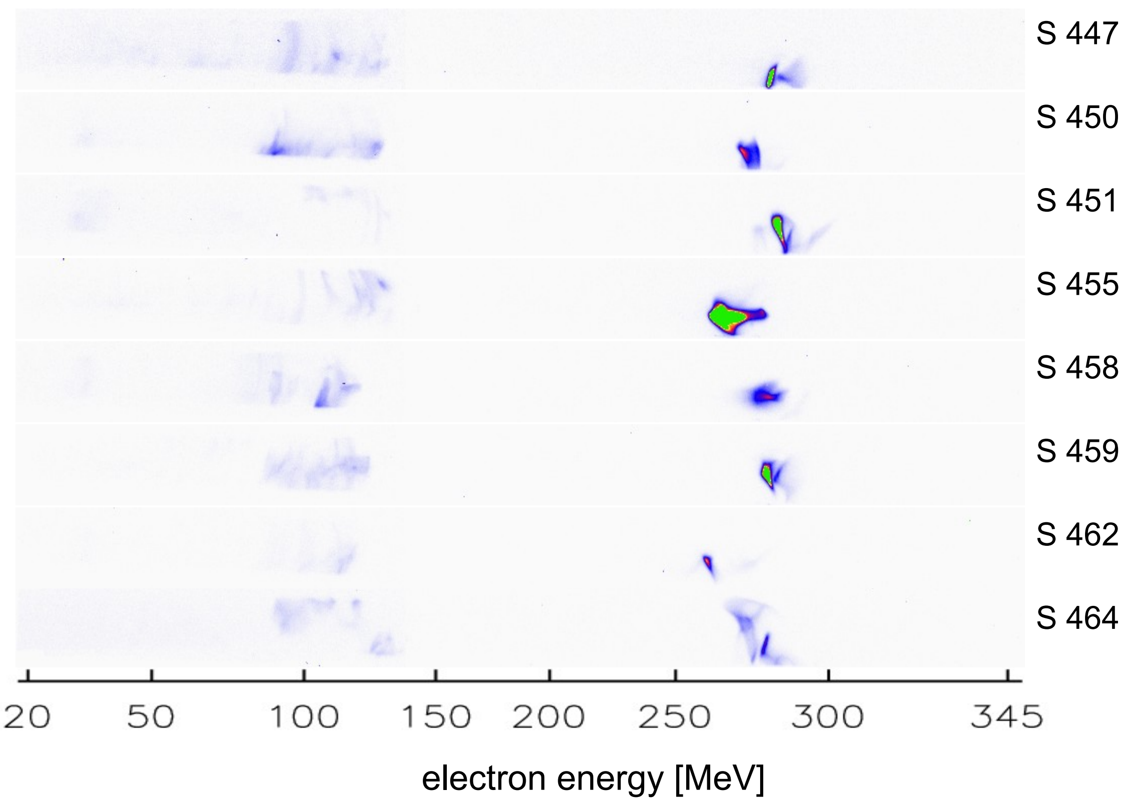

Figure 1: Camera images from magnet spectrometer. Corresponding shotnumbers are annotated to the right.

We used our Amplitude Pulsar 200 System beeing part of MBI's High Field Laser delivering 1.2 J on target with a pulse duration of 25 fs. The beam was focused with an f/15 parabola to a spotsize of $\sigma = 7.9\,\mu m$, yielding a laser parameter $a_0 = 1.85$.

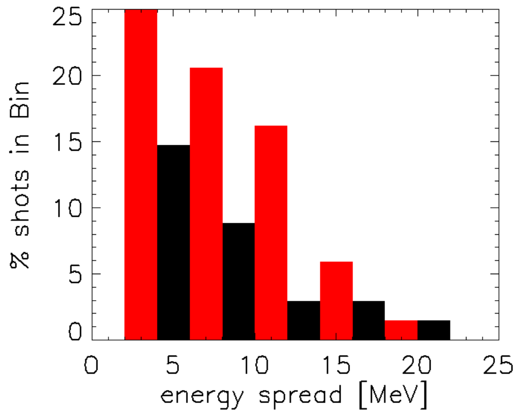

Figure 2: Energy spread distribution for 70 shots at 290 MeV. Bin size = 2MeV

The quasi monoergetic beams have been accelerated above a C-D nozzle with an opening of 2 mm. The average density was $2 \times 10^{18}\,\text{cm}^{-3}$. This yields a cold nonrelativistic wavebreaking limit of 135 GV/m which matches the achieved electron energies. High energy monoenergetic electrons can be achieved, when the razorblade reaches only 50 μm into the opening of the nozzle. The razorblade is mounted at 100 μm above the nozzle. 60 % of the measured spectra showed an energy spread of 2 % FWHM or less.

Magnet spectrometer

Electron spectra were measured using a permanent magnet spectrometer (Fig. 3(a)), which dispersed the electron beam onto scintillating screens (Lanex Fast). The magnetic field of the NdFeB permanent magnets is focused to a peak field 0.7 T using steel chamfers. The peak field resembles a circular segment with a radius of 1.4 m which is the corresponding bending radius of a 1 GeV electron beam at 0.7 T. The gradient of the magnetic field (Fig. 3(b)) causes a focussing in dispersion direction creating a plane, where electrons are detected independent of their input

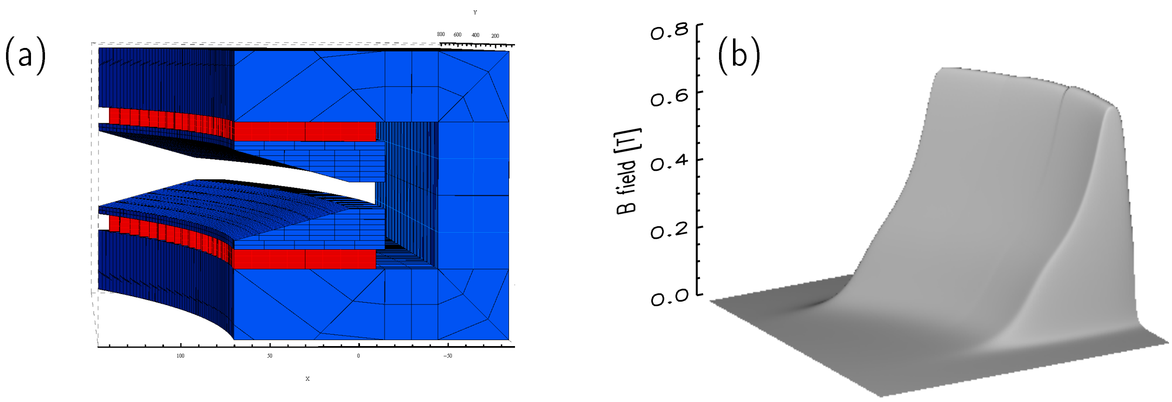

Figure 3: **(a) -** Model of the magnet spectrometer from 'Radia' field modelling software **(b) -** Measured magnetic field in the centered plane

angle, but only dependent on their respective energy. The scintillating screens are mounted directly onto the yoke on the side and the further end of the magnet spectrometer. Fig. 4(a) shows the deviation of the measured energy for electrons with a deviation angle of 1 mrad from the laser axis. An input aperture was placed in front of the magnet spectrometer accepting only electrons with deviations of ±2.5 mrad from the laser axis. To detect energy spreads of 4 MeV, the divergence angle of the electron bunches needs to be smaller then 2 mrad.

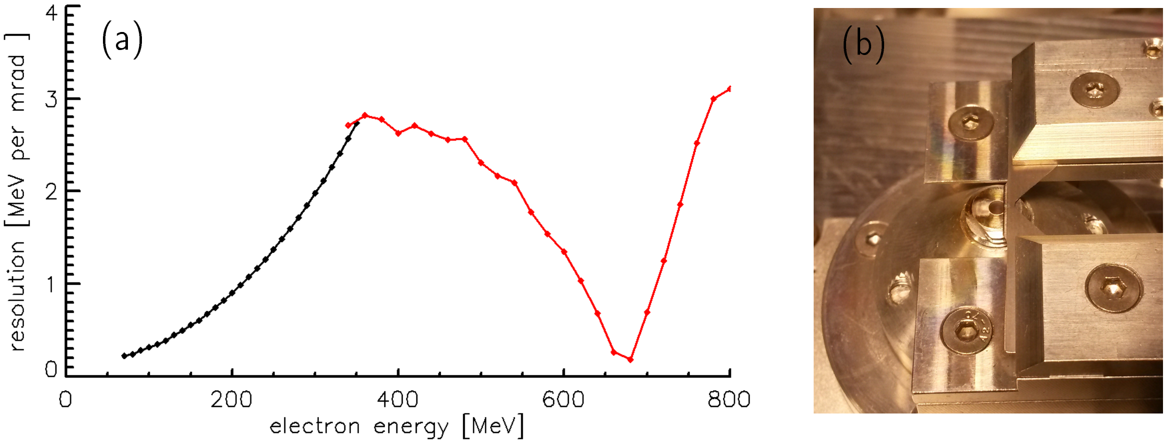

Figure 4: **(a) -** Plot of measured energy deviation per 1 mrad deviation of input angle **(b) -** Nozzle and razorblade

A LANEX Fast screen was placed into the electron beam path before the magnet spectrometer. The average beam divergence was measured at 1.5 mrad. This suggests that our measured spectra are actually resolution limited. The screen showed electrons for every shot and electron bunches with low divergence for 90% of all shots. The pointing has been measured to 3 mrad RMS. The pointing and an additional offset causes 60% of the accelerated electron bunches to miss the magnet spectrometer.

Angular chirp

While density gradients in the plasma target can cause a refractive steering of the laser and thus the electron beam. It has been showen that anuglar dispersion in the beam can also cause a steering and increased pointing of the electron beam [3]. It is suggested that angular chirp (AC) should be compensated to at least $0.2\,\mu\text{rad}/\text{nm}$. In the horizontal plane this can usually be achieved by rotating the compressor gratings around the axis of the grooves. A detune of ε then causes an angular chirp $d\theta/d\lambda = 2\varepsilon\tan\beta_0/(s\cos\alpha)$ with the groove spacing s, input angle α and dispersion angle β_0. This yields an AC of $0.2\,\mu\text{rad}/\text{nm}$ per 0.1 mrad per detuning of our grating. Compensation of vertical AC can be achieved by rotating the grating around its surface normal. This rotation angle is not remotely controllable in our current compressor setup.

Hence we propose a different method to adjust the AC. As wedged windows cause a dispersive refraction as well, two identical wedges can be used to adjust the AC more precisely. The wedges are first placed to exactly compensate each other. As they are rotated in opposing directions their effects cancel out in one direction, but add up in the other. Thus with two fused silica wedges (wedge angle = 3°) we can apply an AC between negative and positive $2.1\,\mu\mathrm{rad/nm}$ by rotating the wedges over 180°. This option will be investigated in future experiments. The horizontal AC has been adjusted using the grating rotation to point electron beams through the aperture of the magnet spectrometer.

The research leading to these results has received funding from Deutsche Forschungsgemeinschaft within the program CRC/Transregio 18 and from LASERLABEUROPE (Grant Agreement No. 284464, EC Seventh Framework Program)

References

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