DPP14-2014-000723

Abstract for an Invited Paper
for the DPP14 Meeting of
the American Physical Society

Multi-GeV electron beams from capillary discharge guided sub-petawatt class laser pulses in the self-trapping regime[1]

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Laser plasma accelerators (LPAs) can produce acceleration gradients on the order of tens to hundreds of GV/m, making them attractive as compact particle accelerators. During the past decade, quasi-monochromatic electron beams at the 1 GeV energy level have been produced using laser pulses at the 40-50 TW peak power level. With the availability of petawatt class lasers, beams up to 2 GeV have been produced from 7 cm long gas cells at UT Austin using 150 J laser pulses and at the 1 GeV level with tails extending to 3 GeV at the GIST facility in Korea. In this talk we present experimental results using the 1 Hz petawatt class BELLA laser at LBNL of the generation of multi-GeV electron beams with center energy up to 4.2 GeV, 6 % rms energy spread, charge approximately 10 pC and an rms divergence around 0.3 mrad. The beams were produced from 9 cm long capillary discharge waveguide structure with a plasma density of $\approx 7 \times 10^{17}\,\mathrm{cm}^{-3}$, powered by laser pulses with peak power up to 0.3 PW. Preformed plasma waveguides allow the use of lower laser power compared to unguided plasma structures to achieve the same beam energy. Detailed comparison between experiment and simulation indicates the importance of the near-field laser transverse mode quality on guiding and acceleration in the LPA. By tuning the plasma density, regimes were found where laser beams with a top hat near-field profile were guided well, and where high energy electron beams can be produced, with narrow divergence [< 0.8 mrad (FWHM)], and relatively small integrated energy spread ($< 10\%$). Provided that the slice energy spread and emittance are sufficiently low, electron beams with this energy could power x-ray free electron lasers. Future experiments will aim at increasing the beam energy to the 10 GeV level.

[1]Work supported by Office of Science, Office of HEP, US DOE Contract DE-AC02-05CH11231