Modulated proton beams accelerated in high contrast laser-plasma interactions from condensed hydrogen jets

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The use of laser driven proton beams for applications like tumor therapy puts strong constraints on the control of the acceleration and on the proton beam properties. This talk will give an overview of the recent achievements at the high-contrast high power laser source DRACO at HZDR using solid density hydrogen jets as a renewable proton source. We demonstrate the feasibility of generating pure proton beams with high repetition rate of up to 5Hz and maximum proton energies of about 20 MeV. Furthermore, the quality of the spatial proton beam profile was found to be sensitive to the pre-plasma conditions, which were measured on-shot with a temporally synchronized probe beam. Distinctive net-like modulations arise from strong filamentary electromagnetic fields produced in a \( \mu \text{m} \)-scale pre-plasma on the rear side of the solid hydrogen target. 3D particle-in-cell simulations confirm that such fields are due to the Weibel instability of the relativistic return current in the rear-side pre-plasma and are in good agreement with the experimental data and analytical estimates. Our results open the way for the generation of high-quality 10s MeV proton beams at high repetition rate for multi-purpose applications.