2025.

AWAKE — As our contribution to the work of the AWAKE Collaboration in CERN [1] we conducted experiments with the schlieren-imaging-based plasma diagnostic. The newly developed setup was used for the first time to investigate plasma column properties simultaneously with the proton bunches that generate wakefields. We proved that the novel design was suitable for gaining valuable information on the plasma channel even in the presence of the proton beam. Theoretical investigations of the laser – Rb vapor interaction process were continued by performing extensive calculations on the wavelength-dependence of the plasma channel properties [2]. These investigations showed how the efficiency of the plasma generation changes strongly in the immediate vicinity of the D_1 and D_2 resonance wavelengths of ground state rubidium. It has been shown that the transient atomic response to the ultra-short, ~ 100 fs laser pulses changes from self-focusing to self-defocusing as the resonance wavelength is traversed (see Figure 1). The behavior resembles strongly the results obtained from a classical anomalous dispersion function theory, even though the short timescale does not allow the use of a dispersion function description.

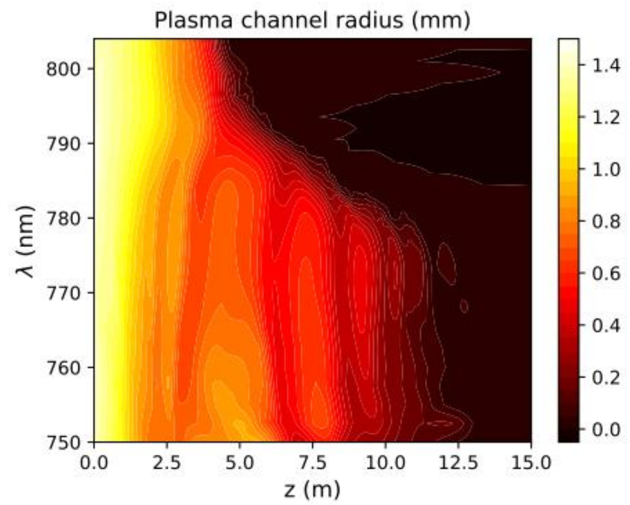

Figure 1. Contour plot of the plasma radius (in mm) as a function of propagation distance (z) and pulse central wavelength (λ).

Mathematical physics — Our decade long activity on solving physically relevant linear and non-linear partial differential equations or equation systems with different kinds of symmetry transformations was continued. This year we had a breakthrough result in cosmology and we managed to explain the Hubble tension with a simple one-dimensional hydrodynamical model. With a rotating dark fluid we could explain why different acceleration Hubble parameters were measured at different objects in the Universe [3]. Work is in progress to develop our model to higher and higher levels of complexity. In a second study we investigated the kinematic self-similar solutions of the spherically symmetric viscous fluid model and presented numerous new solutions [4].

Laser particle acceleration and fusion studies — In the framework of the NAPLIFE project, novel nanostructured targets including thin, nanorod doped foils and oriented nanoparticle arrays were irradiated and Thomson Parabola Spectrometer (TPS) images were recorded. In addition, new semiconductor particle detectors with high bandwidth, integrated signal amplifier and electromagnetic shielding were developed and applied for the detection of charged particles in experiments at Wigner RCP and ELI-ALPS. In Figure 2, detector signals are shown which were taken during the laser shots, as well as using an α particle source. The delay time of the second signal pulse in Fig.2(a) corresponds to accelerated protons in the energy range of about 250-400 keV, in accordance with the particle energies measured with the TPS.

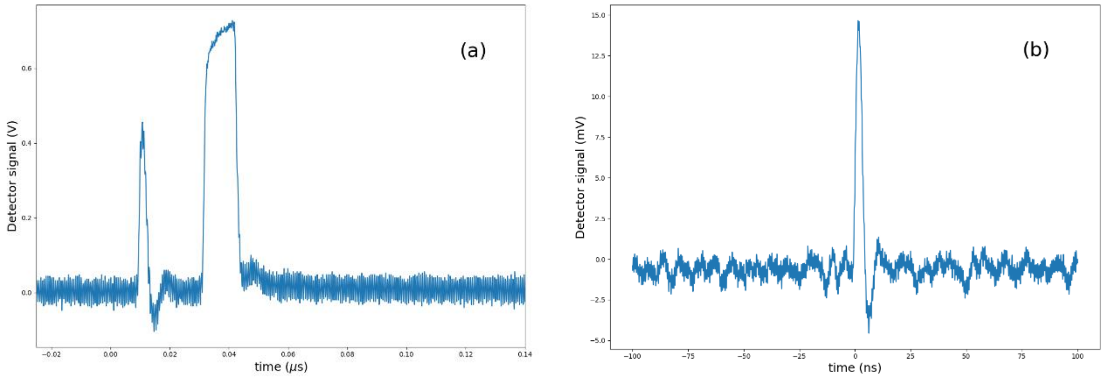

Figure 2. Signals detected by the semiconductor particle detector: (a) during laser irradiation of a nanorod-doped polymer target (the first peak is the photon pulse, the second is the proton signal), (b) detector response to a single α particle from a calibration source.

EuPRAXIA collaboration — Several experiments led by the High-field Terahertz Research Group from the University of Pécs have been carried out at the WRCP laser plasma laboratory. The conversion efficiency of the THz pulse was investigated with different thicknesses of Gires–Tournois etalons, which can generate multi-cycle THz pulses through varying time delays. The efficiency of a novel THz source was also tested and optimized, which incorporated the tilted-pulse-front technique and a volume phase holographic grating. In the framework of the EuPRAXIA Doctoral Network, experiments were performed with a PhD student from the University of Pécs in which a probe laser beam was focused into a gas jet in vacuum where cluster formation occurs due to adiabatic expansion. The spatial and temporal distributions of the average density in the clustering gas were determined by measuring the scattered light.

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