

Novel target development for FAIR*

R. E. Grisenti and R. Dörner, IKF, J. W.-Goethe Universität, Frankfurt/M, Germany

Most of the future experiments at FAIR-NESR require high-density targets to achieve the projected luminosity. One example is the “EXL” collaboration, aiming at the study of nuclear structure properties in light-ion induced reactions (i.e., by using hydrogen or helium beams as internal target). The central part of the experiment is represented by a detector system for the light-ion target-like recoil. The dimensions of the detector system are essentially determined by the spatial extension of the target-beam and the stored ion-beam. Standard gas-jet targets spread out over several millimetres providing an area density of about 10^{14} atoms/cm². A challenging issue is thus represented by the search for new methods aiming to significantly reduce the detector size by increasing at the same time the area density to 10^{15} - 10^{16} atoms/cm² as desirable at the NESR.

Standard internal gas-jet targets make use of Laval-type nozzles with diameter $d \geq 100$ μm . However, such large orifice diameters preclude cooling of the source to temperatures lower than about 80 K as the corresponding flux increase would lead to a strong degradation of the beam properties. The use of very small orifice diameters ($d \sim 1$ μm) appears thus here to be the essential step towards the possibility to increase the target area density by further cooling of the nozzle source to temperatures well below the liquid nitrogen temperature.

The feasibility to producing continuous droplet beams with $N > 10^5$ atoms/droplet by discharging normal liquid and superfluid ⁴He through 2 μm diameter nozzles into vacuum has been demonstrated recently [1]. These experiments allowed a precise characterization of the *true* beam angular profile as a function of the source pressure $P_0 = 1$ -22 bar and source temperature $T_0 = 1.3$ -4.2 K, and a dramatic decrease in the beam divergence either by *increasing* the source pressure or by *decreasing* the source temperature was observed [1]. These results indicate that any angular beam spread in the range 1-100 mrad can be achieved by appropriately choosing the source parameters. This provides a broad range of atomic densities at a given distance downstream from the nozzle exit. In particular, by assuming a uniform droplet beam density and a droplet beam diameter of 1 mm as required for the NESR, area densities in the range 10^{12} - 10^{16} atoms/cm² are indeed achieved.

Systematic investigations of droplet beams have been reported so far only for ⁴He. Much less data are available for molecular hydrogen droplet beams. Most of the work with H₂ concerns studies in the Rayleigh-breakup regime, especially by the Uppsala group [2], who reported on the generation of “pellets” (frozen droplets) by discharging liquid hydrogen through 20 μm -diameter nozzles. How-

ever, the local area density of $\approx 10^{20}$ atoms/cm² makes the possible use of these pellets as internal target at the NESR questionable. In addition, in order to avoid jet freezing at the nozzle exit the liquid hydrogen was discharged into a H₂ atmosphere kept near triple-point conditions, thereby considerably increasing the complexity of the vacuum injection system and the corresponding vacuum pumping stages. Since the nucleation rate decreases with decreasing size, the use of smaller nozzle orifices appears to be crucial to avoid freezing in expansions *into vacuum*.

Preliminary investigations [3] on hydrogen beam generation in the Rayleigh regime by discharging liquid normal hydrogen through a 2 μm diameter nozzle into vacuum demonstrate the feasibility to provide area densities more than one order of magnitude smaller than previously reported [2], as shown in Fig. 1. Most importantly, these results open up the possibility to achieve a broad range of area densities, including those required for the NESR, in close analogy to helium droplet beams [1].

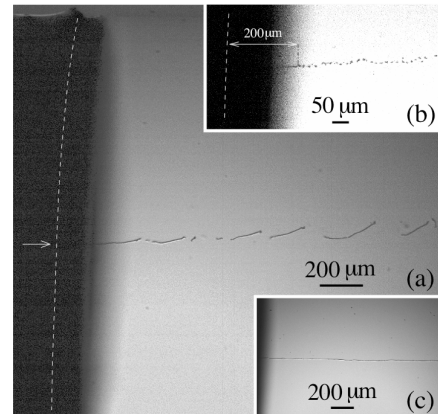


Figure 1: Different breakup modes of a 2 μm diameter hydrogen microjet [3]. (a) The initial filament breaks up into a sequence of rods as a result of apparatus vibrations. The arrow indicates the orifice. (b) Close-up view of Rayleigh breakup. The length of the continuous liquid filament is about 0.2 mm. (c) Example of a continuous solid filament.

References

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