

Improved liquid-jet laser-plasma source for X-ray microscopy

J. de Groot, G.A. Johansson, O. Hemberg and H.M. Hertz

Biomedical & X-Ray Physics, Royal Institute of Technology, 10691 Stockholm, Sweden

Abstract. We increase the x-ray flux from a liquid-jet laser-plasma x-ray source by optimizing the target geometry. A new nozzle fabrication method allows us to produce stable microscopic liquid jets with a wide range of diameters. The improved x-ray flux is demonstrated by optimizing the diameter of an ethanol liquid-jet for our 3 ns, $\lambda=532$ nm Nd:YAG laser and measuring the flux at the $\lambda=3.37$ nm C VI emission line. Preliminary data suggest that the x-ray flux can be increased by more than a factor of 4 compared to previous experiments. The goal is to significantly reduce the exposure time of our laser-plasma-based compact x-ray microscope by improving the source.

1. INTRODUCTION

We have developed a compact sub-visible-resolution water-window x-ray microscope [1]. The microscope is based on an ethanol liquid-jet-target laser-plasma source [2], multilayer condenser mirror and zone plate imaging optics. A short exposure time is a very important parameter for making the microscope operative and useful for users. In the present project we increase the x-ray flux from the source aiming at reducing the exposure times of the x-ray microscope.

The 100 Hz, low debris, high-brightness ethanol liquid-jet laser-plasma source provides water-window ($\lambda=3.37$ nm) radiation from carbon-ion emission with narrow line width ($\lambda/\Delta\lambda=700$). In order to significantly increase the x-ray flux and, potentially, reduce the exposure times in the X-ray microscope, we optimized the x-ray flux from this source by varying the diameter of the liquid jet. Such controlled variation of jet diameter required the development of new nozzles.

2. EXPERIMENTS AND DISCUSSION

The x-ray flux is improved by optimizing the diameter of the liquid ethanol jet for the 3 ns, $\lambda=532$ nm Nd:YAG laser used in the microscopy experiments. Since the commercial nozzles used in previous experiments have a fixed jet diameter (approx. 10 μm), we have developed a new nozzle fabrication method. The new nozzles consist of fused silica capillary tubing connected to a standard HPLC filter. With help of a micropipette puller and standard polishing methods, nozzles are produced with a jet diameter between 8 and 100 μm with a repeatability of 2 μm [3].

Figure 1 depicts the experimental arrangement. The special aspects of the arrangement is described briefly here but the reader is referred to Ref. 2 for a general background. The liquid jet is created by forcing ethanol through the nozzle at a pressure of 100 bar resulting in a speed of >80 m/s. The background pressure is approx. 10^{-3} mbar. The pulsed Nd:YAG laser is focussed on the jet and the relative flux at the $\lambda=3.37$ nm C VI emission line is measured for different jet diameters using a filtered diode. The $\text{N}_2/\text{O}_2/\text{Si}_x\text{N}_x/\text{Ti}$ filter assembly provides sufficient suppression of other emission lines. Accurate spectral measurements are on their way for improved understanding of the laser-plasma physics. The standard deviation in the measured x-ray flux is 12% shot-to-shot, which is comparable to earlier experiments with the commercial nozzles.

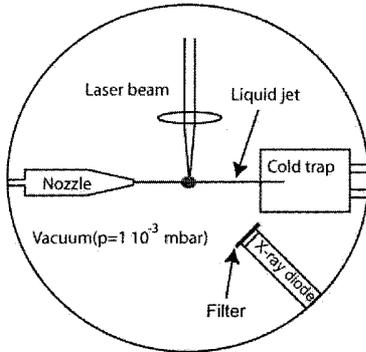


Figure 1. Schematical set-up for the size of target optimization

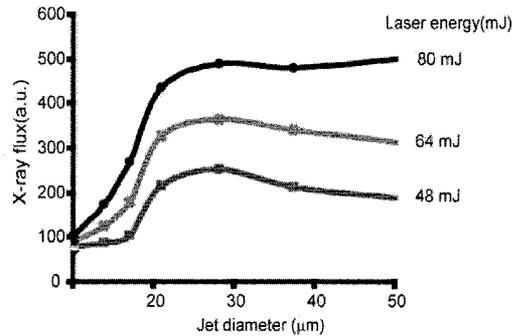


Figure 2. X-ray flux as function of the jet diameter for different laser energies. The X-ray flux is measured at the opposite site of the laser beam

Figure 2 shows preliminary data suggesting that the x-ray flux can be increased by more than a factor of 4 compared to previous experiments. However, since the x-ray flux is measured on the opposite side of the laser beam (cf. Fig. 1) we expect that the jet shields x-ray emission for larger jet diameters, making higher enhancements possible with a different spatial arrangement. Parallel with the laser-plasma flux experiments, debris is measured by exposing witness plates placed 2-3 cm from the plasma and later determining quantitative debris flux by optical absorption measurements [5]. As expected, debris production increases almost linearly with the diameter of the liquid-jet target. Since a high debris load will contaminate the x-ray optics, our current estimate is that this optimization will result in an increase in the "useful" flux of 2-3 times for ethanol target, compared to previous system. More accurate debris measurements as well as measurement of absolutely calibrated spectra are currently performed.

References

- [1] G. A. Johansson, A. Holmberg, H. M. Hertz, and M. Berglund, *Rev. Sci. Instrum.* **73**, 3 (2002).
- [2] L. Rymell and H.M. Hertz, *Opt. Commun.* **103**, 105 (1993); L. Rymell, M. Berglund and H.M. Hertz, *Appl. Phys. Lett.* **66**, 2625 (1995); L. Malmqvist, L. Rymell, M. Berglund and H.M. Hertz, *Rev. Sci. Instrum.* **67**, 4150 (1996).
- [3] J. de Groot et. al., in preparation for *Rev. Sci. Instrum.*
- [4] T. Wilhien, S. Rehbein, D. Hambach, M. Berglund, L. Rymell, H.M. Hertz, *Rev. Sci. Instrum.* **70**, 3(2002)
- [5] L. Rymell and H.M. Hertz, *Rev. Sci. Instrum.* **66**, 4916 (1995)