

Characterization of the gain region in transient X-ray lasers

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In order to perform high resolution laser spectroscopy on the $2s_{1/2}$ - $2p_{1/2}$ transition in lithium-like heavy ions at GSI a transient X-ray laser (XRL) is currently under construction [1] which will be pumped by the 10-J short pulse frontend of the PHELIX laser system [2]. In the frame of GSI's XRL activities a joint experiment has been carried out in collaboration with the XRL research groups from the Université Paris-Sud and the University of York [3]. The aim of this work was to gain insight in the complex plasma dynamics and laser amplification process and hence to identify parameters relevant for beam divergence, homogeneity, or spatial coherence improvement.

The experiment was done at the 100 TW-facility of the Laboratoire Utilisation des Lasers Intenses (LULI) at Ecole Polytechnique (France). The system is a hybrid Ti:Sa-Nd:Glass CPA laser system which is capable of delivering pulses of up to 35 J with a duration of 350 fs.

In a typical transient XRL a long (~1ns) prepulse is focussed to a line creating a line shaped plasma of preferably Neon-like or Nickel-like ions. This plasma is then rapidly heated by a short laser pulse of high intensity thereby creating population inversion and a high transient gain leading to amplified spontaneous emission (ASE) in the soft X-ray range.

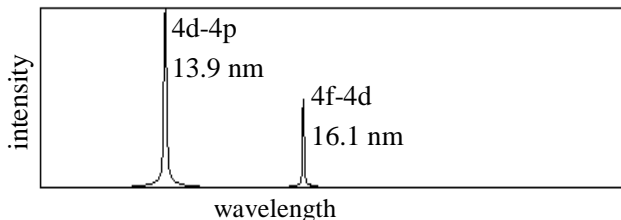


Fig. 1: Output spectrum of the Ni-like silver x-ray laser.

Pulse energies of up to 20 J in the short pulse and up to 40 J in the prepulse were used to create line foci of up to 10 mm in length. Two independent focussing arrangements were used for the long and the short pulse, respectively, which allow the separate adjustment of the width of the respective line focus. The prepulse which arrived (660 ± 50) ps before the peak of the short pulse was focused by a combination of an aspherical lens and a cylindrical lens. For the short pulse an arrangement of an off-axis parabola and a spherical mirror was used. This arrangement produces a travelling wave excitation in the line focus with a speed of ~2.7 times the speed of light. For velocity matching of the short lived gain and the ASE photons this speed was slowed down to c by tilting the pulse front, which is achieved by means of a slight and controlled misalignment of the pulse compressor [4]. A typical spectrum obtained from the XRL is given in Fig. 1 showing strong lasing from Ni-like silver ions at 13.9 nm and 16.1 nm.

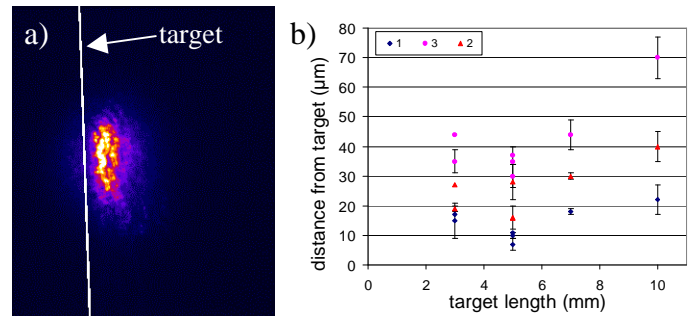


Fig. 2: a) High resolution image of the XRL output plane. b) Vertical size of the emitting region as a function of target length.

The main diagnostic was an XUV imaging system developed by the Institut d'Optique (France) which provides time integrated 2D-images of the output plane of the XRL (Fig. 2a). This device was designed to avoid geometrical aberrations with a high magnification factor, so that a resolution of 1 μm , only limited by diffraction, was achieved [5]. This confirmed an earlier observation of double-spots structures. As an additional diagnostic, a so-called cross-slit camera, developed and built at GSI, provided a full length side view

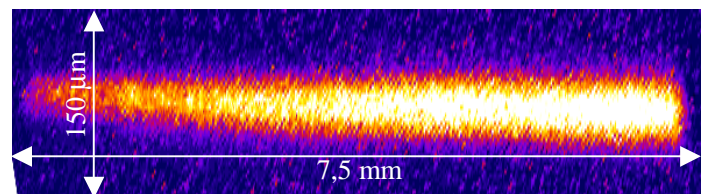


Fig. 3: Time integrated image of the keV radiation of the hot XRL plasma. The longitudinal intensity distribution reflects the distribution of the pump laser.

of the plasma with a transverse resolution of 10 μm , imaging the keV radiation of the hot plasma (see Fig. 3). The data of the two diagnostics agree well and clearly reflect changes in the pumping conditions. The observed increase in the width of the "hot" plasma regions could explain the observed increase of the emitting region (Fig. 2b).

References

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