Heavy-Ion-Beam Pumped Excimerlaser ◇

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The use of heavy-ion beams for pumping gas-lasers had first been demonstrated in 1983 by pumping an infrared He-Ar laser with a 100 MeV ^{3}2S beam from the Munich Tandem van de Graaff accelerator [1]. Since then various schemes for ion beam pumped lasers have been studied [3-5] and amplified spontaneous emission was observed at GSI for the VUV xenon excimer transition at 172 nm [2]. In this report we describe the first successful operation of a UV excimer laser using a pulsed heavy ion beam from the heavy ion synchrotron SIS at GSI. The experiment has become possible due to the improved beam intensity and quality which is now available at the HHT target area. The well known KrF^* excimer laser line at a wavelength of 248 nm has been selected for a first demonstrational experiment. The laser setup consisted of a 1.2 m long stainless steel tube of 30 mm diameter placed about 2 m behind the exit foil of the HHT beamline. A pulsed beam of ^{238}U ions with a particle energy of 250 MeV/u and 110 ns pulse duration (FWHM) was used for pumping. The projectiles traversed 2 m of air, a 600μm thick scintillator, a stainless steel entrance foil, a 3 mm thick glass mirror substrate, and were then stopped in the laser gas mixture. Single shot pulses of up to 2.5×10^9particles/pulse were focused into the laser cell. The energy of the particles entering the optical resonator was reduced to less than 100MeV/u which corresponds to a pulse energy of about 9 J. Assuming an average beam diameter of 5mm this corresponds to an average energy density of about 0.5 J/cm^3 and a pumping power density of 5 MW/cm^3 in the laser gas. The optical resonator was formed by a flat, Al-coated mirror near the beam entrance and a second dielectrically coated, highly reflective mirror with 3 m radius of curvature at a distance of about 1 m. This end mirror was also used as an optically transparent window for the cell and for decoupling the light from the resonator. A laser gas mixture of approximately 50% Ar and 50% 99.5/0.5 Kr/F_2 was used as the laser medium. A constant gas flow was maintained to avoid F_2 depletion due to chemical reactions. Two fast UV enhanced photodiodes with 248 nm filters and two small monochromators with fiber optics input were used for laser diagnostics. Light emitted along the laser axis was diffusely reflected off an Al-plate before detection. Beam alignment was performed by steering and focusing a low intensity beam of about 10^8 particles/pulse into the laser cell. Spontaneous emission near the end of the cell was observed with cameras. For a gas pressure of 1.6 bar the range of the ions matched the length of the cell. When the beam intensity was raised to about 2×10^9 particles/pulse laser effect was immediately observed by a strong appearance of the 248 nm line in the spectrum emitted along the laser axis. Laser threshold was reached with 1.25×10^9 particles/pulse for this specific setup. Spectra recorded with 1.0 and $1.3{\times}10^9$ particles/pulse, respectively, just below and above threshold, are shown in Fig. 1. The broad-band Kr_2F^* emission around 400 nm shows only a slight intensity difference of about 30% in the two spectra as can be expected for a non-lasing transition in contrast to the 248 nm laser-light. Note, that the end mirror is highly reflective for 248 nm light and transmissive at 400 nm.

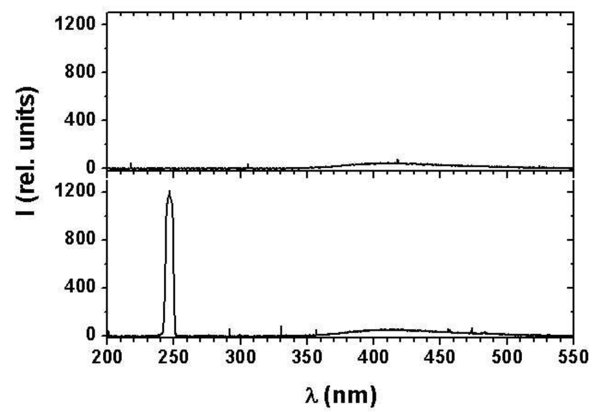

Fig. 1: Emission spectra from KrF along the laser axis just below (top) and above laser threshold. Laser effect is clearly visible by the strong 248 nm emission.

The time structure of the emission of spontaneous as well as laser light at 248 nm was recorded with the photodiodes. The half-width of spontaneous emission was 130 ns and the laser pulse duration ranged from 59 to 84 ns for pumping intensities between 1.4 and $2.5{\times}10^9$ particles/pulse. A first indication of spectral narrowing was also observed by comparing spectra of spontaneous and laser emission, respectively. However, the actual line widths could not be measured due to the limited resolution of the spectrometer used. In summary it could be shown that the pumping power and beam quality of the heavy-ion synchrotron SIS at GSI Darmstadt is now sufficient to pump UV lasers and it is planned in a next step to extend the laser experiments into the VUV range of the spectrum (<200 nm).

References

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