A Solid State Laser System for the Cooling of Magnesium Ions

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Introduction: Sympathetic cooling of ions in Paul and Penning traps would be advantageous for proposed experiments at the TRIGA reactor Mainz as well as at GSI Darmstadt. Magnesium ions are favourable for such a cooling scheme since they have a closed two-level system and lasers for repumping are not required. However, light at the transition wavelength of 279.5 nm has to be produced either by frequency doubling of a dye laser or frequency quadrupling of a fiber laser. We have chosen the solid state approach and the system will later be composed of a 1.5 W fiber laser at 1118 nm and two second harmonic generation (SHG) cavities for frequency quadrupling. Currently we are setting up the first doubling-stage for a fiber laser and we will later apply the system at the TRIGA-SPEC as well as on the SPECTRAP setup at GSI.

Experimental: We used a Koheras Boostik fiber laser as the fundamental laser source for the first SHG cavity. The laser has 1.5 W maximum output power, less than 70 kHz linewidth and a very good beam quality: M^2 less than 1.05. The output polarization can be optimized and controlled with a quarter- and a half-waveplate. An optical isolator is used for avoiding back reflections in the laser (figure 1).
For the first SHG cavity we used a LBO nonlinear crystal because of its high damage threshold and the possibility to use the more efficient non-critical phase matching (NCPM) at 89°C, type I XY/XZ, θ=90°, φ=0°[1].
Using the Boyd Kleinman [2] theory and evaluating the optimizable parameters, we came to an optimum length of 20 mm for the crystal. Considering that we use NCPM and the walk-off angle between fundamental and second harmonic light is 0°, the optimum focus inside the crystal with this length is for a beam waist of 28 µm.
For the cavity we had to estimate all losses of the fundamental laser light: from doubling, surface reflections and due to the absorption inside the crystal. Therefore, we chose a 97.5% reflectivity at 1118 nm of the input mirror M1 for impedance matching. This corresponds to a cavity enhancement factor of 40.

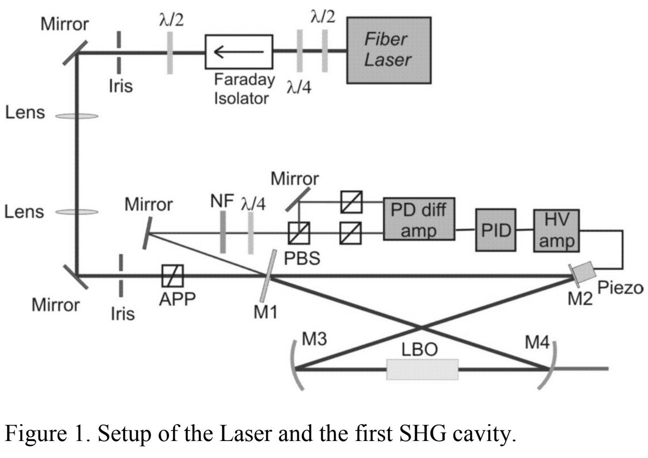

Figure 1. Setup of the Laser and the first SHG cavity.

Using the ray transfer matrix analysis [3] we designed a bow tie resonator that allows us to fit the oven with the crystal in the middle of the short arm and to obtain a 28 µm beam waist in the middle of the crystal (see Fig. 2).
M1 is AR coated for 1118 nm on the outside relative to the cavity. M2 is highly reflective (>99.9%) for 1118 nm and is mounted on a piezo mirror shifter for fine adjustments of the cavity length. For the focusing arm we used two plano-concave mirrors with f=70 mm and with a distance between of d=154 mm. M3 is highly reflective (>99.9%) for 1118 nm while the output coupler is highly reflective (>99.8%) for 1118 and transmissive (T>94%) for the second harmonic wavelength of 559 nm.

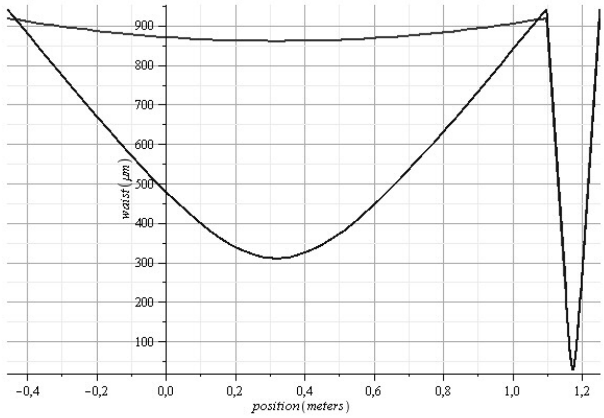

Figure 2. Beam waist size inside the cavity for the sagital and tangential plane.

The total length of the cavity is 1709 mm and has a full folding angle of 30°. Because of this big folding angle we obtained an astigmatic focus in the middle of the long arm and we had to use an anamorphic prism pair besides two convex lenses in order to obtain a proper mode matching.
For locking the cavity we used the Hänsch-Couillaud polarisation analysis locking scheme [4].

Results: We obtained up to 75% coupling efficiency of the fundamental beam into the cavity. Locking was stable for power inputs up to ~500 mW. The maximum green output was approximately 50 mW for 950 mW fundamental power at the input.
Further efforts must be made in order to increase the efficiency of the doubling by better alignment and reduction of losses and for increasing the locking stability at higher power levels.

References

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