High-Power Tunable Infrared Laser Source

M. Würtz[a], S. Borneis[b], T. Kühl[b], F. Laeri[a], D. Marx[b], T. Tschudi[a]

[a] Institut für Angewandte Physik, TU Darmstadt; [b] GSI Darmstadt

Laser spectroscopy experiments at the ESR [1, 2] require high-power laser sources at various wavelengths from the ultraviolet to the infrared spectral range. To be able to measure ionic transition energies, either the laser wavelength or the velocity of the ions needs to be tunable. In both cases, the wavelength of the transition is shifted due to the Doppler effect. The accuracy of such measurements can be significantly enhanced up to a factor of 100 when two lasers are used in antiparallel geometry. If both lasers can be tuned to the same resonance transition, the ion velocity may be determined with a accuracy of 10^{-6}. Taking into account that the ion velocity is tunable by changing the electron cooler voltage requires that at least one laser needs to be tunable.

Optical Parametric Oscillators (OPO) provide such tunable laser sources. In an OPO, the radiation of a pump laser at the frequency ω_p is split up by difference frequency generation in a nonlinear optical crystal according to:

$$\hbar\omega_p = \hbar\omega_s + \hbar\omega_i \text{ (energy conservation)} \quad (1)$$

$$\hbar\vec{k}_p = \hbar\vec{k}_s + \hbar\vec{k}_i \text{ (momentum conservation)} \quad (2)$$

$\hbar\omega_{s,i}$ and $\hbar\vec{k}_{s,i}$ denote the energy and momentum of the so called "signal" (short wavelength) and "idler" (long wavelength) beam, respectively. When all waves propagate in the same direction, equation (2) is equivalent to $n_p\omega_p = n_s\omega_s + n_i\omega_i$. The refractive index $n = n(\omega, \theta)$ of the crystal depends on the light frequency and on the angle of incidence of the pump beam with respect to the crystal axis. Both equations may just be satisfied if a birefringent crystal and different planes of polarization are provided. The wavelength tuning is typically achieved by rotating the crystal. Figure 1 shows the wavelength dependence of the two output beams upon the angle of incidence in a BBO (β-barium borate) crystal, pumped at 532 nm. The calculated gain curve is very flat in this case.

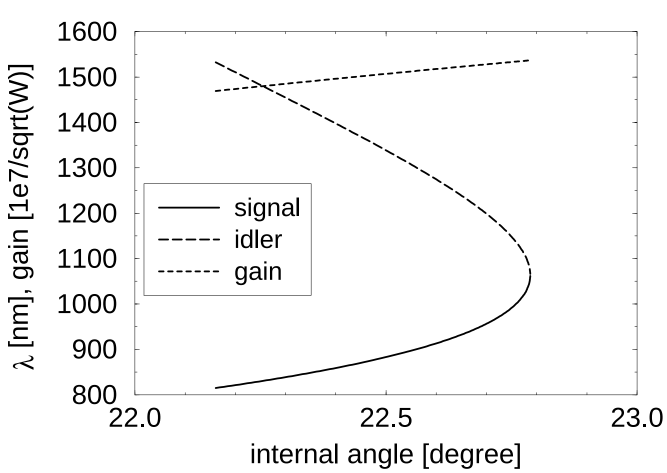

Figure 1: Angle tuning curve of a typical BBO crystal pumped at 532 nm

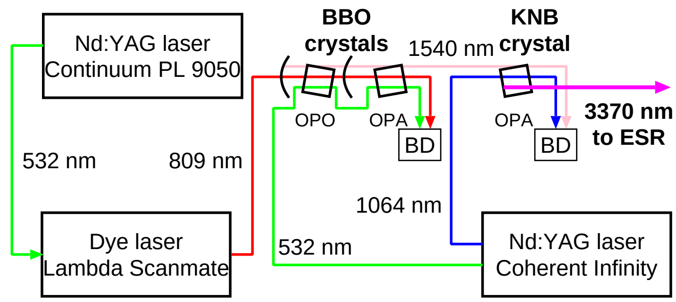

Figure 2: The two-stage OPO/OPA system (mirrors and lenses are not shown). To achieve optimum beam quality at the crystals, the pump beams are guided through a relay imaging system.

An OPO/OPA (Optical Parametric Amplifier) combination as depicted in Figure 2 was developed for the recent beam time (Dec 98, E025). The first stage consists of a BBO crystal inside of an unstable confocal resonator, followed by a second crystal operated as an amplifier (OPA). The unstable resonator provides a low-divergence output beam with a diameter of 4 mm. The high beam quality is crucial for the 20 m propagation to the ESR. The crystals are pumped by the frequency doubled output of a Nd:YAG laser (Coherent Infinity, 300 mJ at 532 nm, 50 Hz repetition rate) and seeded with the output of a pulsed, tunable dye laser (Lambda Physik Scanmate, 25 mJ at 809 nm). The seeding technique provides higher output power, narrow bandwidth and lower beam divergence. The pump beam is guided around the output coupling mirror in order to avoid optical damage. After passing the amplifier crystal it is directed into a beam dump (BD).

The output energy of signal and idler of the first stage was 116 mJ at a repetition rate of 50 Hz, with 27 mJ at the desired wavelength of 1550 nm. This corresponds to an average power of 1.35 W.

An additional single crystal KNB (potassium niobate, $KNbO_3$) OPA stage finally generates the 3370 nm wavelength needed for the experiment. This is achieved by difference frequency generation of the attenuated residual 1064 nm output of the Infinity Nd:YAG laser and the 1550 nm idler wave of the BBO OPO/OPA stage. At a pump level of 65 mJ, the output energy was 2.2 mJ.

References

[1] P. Seelig et al., *Phys.Rev.Lett.* **58**, 4824-4827 (1998)

[2] H. Winter et al., *Hyperfine Interactions* **114**, 207-211 (1998)