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# Wavelength selection, spatial filtering and polarization control of an Er:YAG laser cavity by resonant-grating mirror

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Er:YAG crystals are good candidates for eye-safe solid-state lasers with output pulses energy in the mJ range, which are required for applications in atmospheric propagation such as active imaging, lidar and wind mapping. Er:YAG crystals can emit at 1645 nm or 1617 nm. The laser emission of Er:YAG naturally occurs at 1645 nm and is unpolarized. In addition, the required high incident pump powers in quasi-three-levels laser such as Er:YAG could lead to a poor beam quality factor ($M^2$) because of well-known thermal effects in rod lasers.
Some applications may require emission at 1617 nm with a good $M^2$ factor for long range sensing, as well as linearly polarized output beams for pollutant probing [1]. Therefore, a basic Er:YAG cavity could be provided with an intra-cavity etalon for wavelength selection [2], a reflective polarizer for polarization control, and a pinhole for spatial filtering. In this contribution, we report on a resonant-grating mirror (Fig. 1 left) which can be used to fullfil these three functions, hence simplifying the laser setup [3].

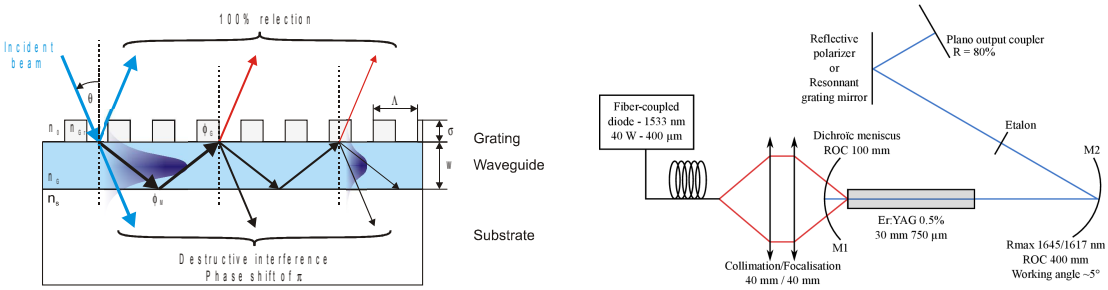


**Fig. 1** (**left**) Schematic description of the resonant reflection principle. (**right**) Experimental setup of the cavity. The pinhole, the etalon and the reflective polarizer can be removed by inserting the resonant-grating mirror in place of the reflective polarizer without losing the wavelength selection, the polarization control and the spatial filtering.

For the experimental investigation, an Er:YAG single crystal fiber from Fibercryst with a diameter of 750 µm, a length of 30 mm and a doping concentration of 0.5 % is used as gain medium (Fig. 1 right). The fiber end faces were anti-reflection coated and the crystal was actively cooled to 12°C. The pump light was provided by a fiber-coupled laser diode with a core diameter of 400 µm and a numerical aperture of 0.22, delivering up to 40 W at 1532 nm. Its spectrum was narrowed down to approximately 1 nm by an internal volume Bragg grating. The beam was collimated by a doublet of 40 mm focal length and focused at a few millimeter inside the Er:YAG crystal by a second doublet of the same kind. The cavity was made from two concave mirrors and a plan output coupler with a reflectivity of 80 %. As the reflective polarizer and the resonant grating mirror are best used with a collimated beam, the distance between mirrors M1 and M2 was adjusted accordingly.
In a first reference setup, an etalon and a plan reflective polarizer were inserted inside the cavity. An output power of 2.15 W was emitted at 1617 nm with a $M^2$ of 4.0 and 6.0 for both axis respectively. The degree of linear polarization of the emitted beam was measured to be 94.8 %.
The resonant grating mirror (RGM) used in our experiment is composed of fused silica substract and a single high-index layer ($Ta_2O_5$) in which a grating with a period of 703 nm and a groove depth of ~50 nm was integrated. It was inserted as a folding mirror in the above described cavity. The incident angle was chosen precisely to achieve the resonance i.e. a high reflectivity at 1617 nm. An output power of 1.43 W was obtained at 1617 nm with a $M^2$ factor of 1.4 and 1.6 for both axis respectively. The degree of linear polarization was measured to be 95.8 %.
Thus, a huge improvement in the beam quality factor, a comparable (to the etalon-polarizer combination) polarization purity and spectral bandwidth of the emitted beams were achieved with the RGM. However, a drop of 33 % of maximum output power was observed. The latter might result from a slight misalignment of the RGM as well as from its intrinsic losses (absorption and scattering). Further experiments could lead to higher output powers with this mirror.
In conclusion, we demonstrated an innovative design for wavelength selection, spatial filtering and polarization control of a laser cavity by using resonant-grating mirror.

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