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Comparative study on pump wavelength dependent efficiency in Nd:YVO$_4$

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Abstract: The influence of the pump wavelength on the heat load and efficiency of Nd:YVO$_4$ crystals is investigated with a specially designed crystal mount. The measurements indicate that the change in heat load in the crystal can be solely ascribed to the difference of quantum defects and no further non-radiative effects.

Laser sources for future generations of gravitational wave detectors (GWDs) need to fulfil the requirements of high fundamental mode content, linear polarization and low noise properties at high power levels over 500 W at 1064 nm [1]. Nd:YVO$_4$ is a promising material to fulfil these requirements. Due to the large absorption cross section, Nd:YVO$_4$ is usually pumped at 808 nm. However, there is also an absorption line at 878 nm, which enables pumping directly into the emitting level and thereby reduces the quantum defect and the associated heat load.
In this work, we studied the efficiency of Nd:YVO$_4$ with a focus on the heat deposition in the crystal. For this, we developed a custom crystal mount, which is shown in Fig. 1, left. The lower part of this mount is temperature stabilized by a Peltier-element mounted on a water-cooled heat sink. The resulting heat gradient along the crystal mount is measured at different pump power levels via two temperature sensors. Before the measurement, a calibration was carried out by heating the mount via pt100 resistors. In order to achieve a similar absorption behavior along the crystal for both pump wavelengths, the 808 nm pump diode was slightly temperature shifted. This way, we achieved a similar amount of absorbed power at the same input pump power levels for both pumping schemes.

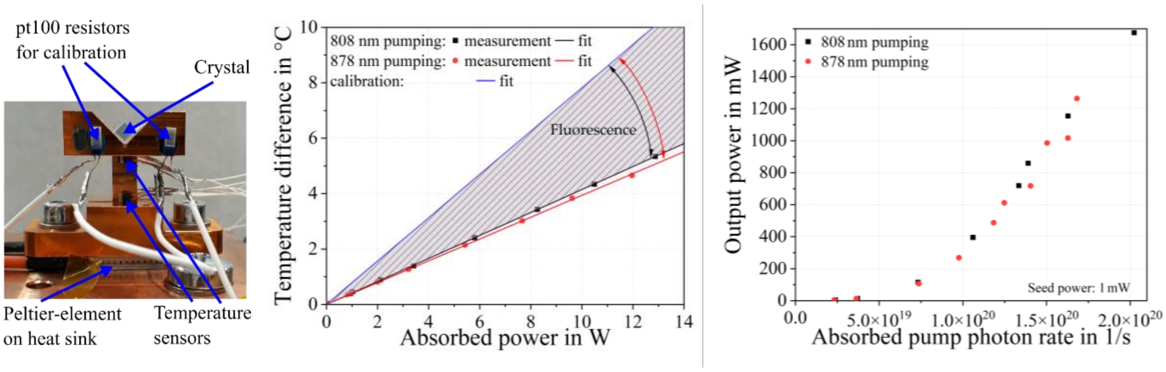

Fig. 1, left: crystal mount for thermal measurements, middle: temperature difference between temperature sensors over absorbed pump power, right: amplifier output power over absorbed pump photon rate

Fig. 1, middle shows the resulting temperature differences for different absorbed pump powers as well as the calibration curve (blue). The difference between the calibration curve and the measured values can be attributed to the fluorescence, as this is the only effect that does not contribute to the heat load. The ratio of the fluorescence measured at both pump wavelengths corrected by the quantum defect is approx. one. Thus, the difference in heat generation and in fluorescence can be explained solely by the quantum defect. Other non-radiative processes are negligible within the scope of our measurement accuracy. As this measurement was performed without any laser light extraction besides fluorescence, it was repeated with a laser resonator built around the crystal. Also here, the measured temperature difference could be explained just by the quantum defect.
Furthermore, an amplifier was set up in order to measure the pump wavelength dependent efficiency. Fig. 1, right shows the output power at different pump photon rates for both pump wavelengths. The output power per pump photon was independent from the pump wavelength within our measurement accuracy. Hence, pumping at 878 nm leads to less deposited thermal power and thus less thermal lensing effects than pumping at 808 nm at the same output power and the exact difference can be calculated by the quantum defect.

[1] ET Science Team, "Einstein gravitational wave Telescope conceptual design study" (2011), URL: https://apps.et-gw.eu/tds/ql/?c=7954