Cryogenically-cooled two-micron solid-state lasers: Recent results and future prospects

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Efficient powerful laser sources in the two-micron regime are in demand for many applications in the areas of remote-sensing, defence, medicine, and materials interactions. Recently, dramatic progress has been shown in scaling cw output power from 2-micron fibre lasers [1]. Very high efficiency, good beam quality and wavelength flexibility are key attributes of the fibre-laser architecture, owing to the high gains achievable, waveguiding properties of the core, and a geometry which offers excellent thermal management. However, in a pulsed mode of operation, scaling of output power and pulse energy in optical fibres is limited by nonlinear effects and a relatively low damage threshold power, due to their long device lengths and small core areas. Conventional 'bulk' solid-state lasers on the other hand, have the potential for high pulse-energies due to their large cross-sectional area, their main obstacle though is susceptibility to thermal effects in the laser medium resulting from heat generated during the pump cycle. Mitigation of these detrimental effects can be achieved by cooling the gain medium to cryogenic temperatures[2], benefitting from a large increase in the thermal conductivity, with a proportional decrease in the thermo-optic coefficient (dn/dT) and thermal expansion coefficient at these very cold temperatures. Combined these result in a massive reduction in thermo-optic aberrations, with further benefits derived from lower reabsorption losses as the cold gain medium is 'four-level' in character, ultimately allowing relatively simple laser resonator configurations to be used that are not possible at room temperature. In this paper, we report current laser performance of a cryogenically cooled Ho:YAG laser in-band pumped by a narrow-linewidth Tm fibre laser and discuss future prospects for high-power operation in pulsed or CW regimes.

Two important aspects of cryogenically-cooled Ho:YAG lasers will be discussed, the first; our measurement of the 'cold' absorption spectrum, for which only under-resolved information was available in the literature. Utilising a multi-Watt Tm:fibre ASE source we have been able to properly identify the absorption features of interest at various temperatures between room and liquid nitrogen (LN) temperatures, with an accuracy better than 0.2nm. Secondly; we detail the laser performance of comparable 2.1-micron Ho:YAG lasers at room and LN temperatures, demonstrating improved performance associated with the 'four-level' character of the gain medium at LN-temperature, in addition to reduced thermo-optical aberrations. Where we have used our own custom-made narrow-linewidth (<0.2nm) tuneable Tm:fibre laser as the pump source. Furthermore low quantum defect operation was realised by operating the Ho:YAG at a wavelength of 1970nm with a pump wavelength of 1932nm, implying a QD of <2%.

We will demonstrate that dramatic power-scaling advantages in 2-micron laser performance can be realised by simply cryogenically-cooling the laser gain element, in comparison with an equivalent room temperature crystal. The potential for further power and energy scaling will be discussed, including what benefits may be realised for other gain media in this wavelength regime.

References

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