# Hybrid Ho:YAG laser with 50W radially-polarised output

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Holmium doped radially polarised lasers operating in the 2.1 µm spectral region are of great interest as they provide benefits of operation in the atmospheric transmission window (2.1-2.25 µm), absorption in transparent polymers, as well as the materials processing benefits that are beginning to be realised from utilising select higher order modes [1]. We report on the development of a 50W CW radially polarised Ho:YAG laser operating at 2090nm.

Power scaling of Ho:YAG laser systems is generally limited by availability of high power pump lasers in the 1907 nm region. Here we use an internally-developed, all-fibre 200 W-class multimode 1907 nm pump laser. Five 45 W single mode all-fiber FBG-locked Tm lasers are multiplexed in a tapered fibre combiner to provide > 200 W in a 105/125 µm 0.22 NA pump delivery fibre. This fiber is spliced onto a low-loss taper that transfers the pump power into the glass guidance of a capillary fibre (200µm diameter & 100µm hole with 220µm fluorine-doped 0.22NA glass cladding, see fig 1). The laser cavity is formed around an end-pumped 0.5 at. % doped Ho:YAG crystal of 5 mm diameter and 40 mm length, and between the pump input dichroic (laser high-reflector) and a 10% laser output coupler. The annular pump light is relay-imaged from the capillary facet into the Ho:YAG crystal by f = 25.5 and 200 mm lenses, resulting in a 1.6 mm beam diameter in the crystal. This provides a ring-shaped inversion profile in the laser crystal giving preferential gain to the set of $LG_{0n}$ modes. An intra-cavity f = 50 mm lens is utilised to control the size of the cavity modes, and therefore their overlap with the spatially-distributed gain, allowing selection of preferred laser modes. Thermally-induced birefringence in the crystal provides a differential cavity stability between unpolarised, radially and azimuthally polarised modes and, with control on the position of the intra-cavity lens, operation on the radial mode is readily selected [2, 3].

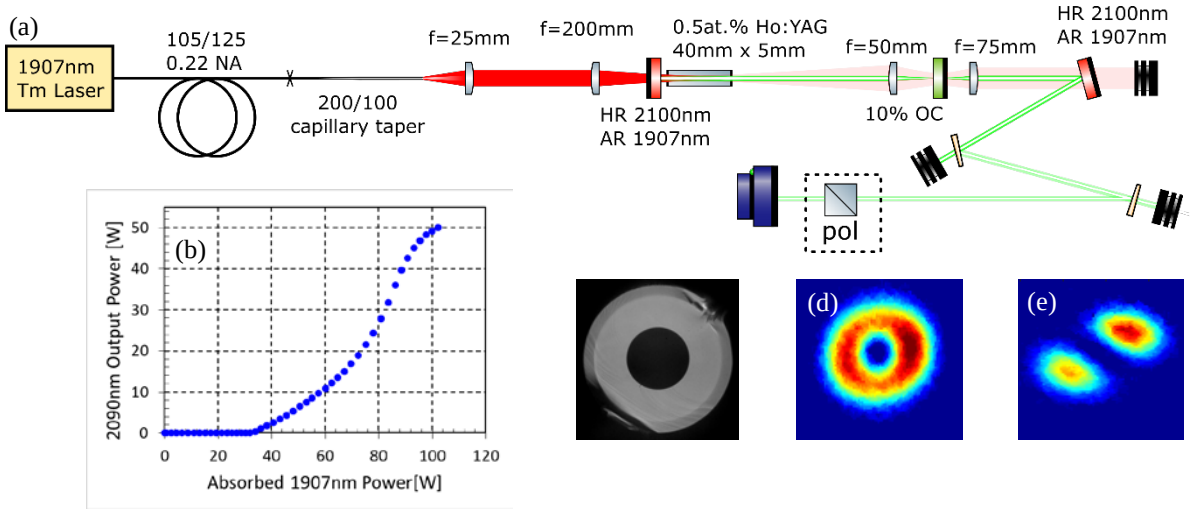


**Fig. 1** (a) Ho:YAG laser cavity schematic showing the pump imaging of the capillary pump delivery fibre into the Ho:YAG crystal. (b) Output power curve from the Ho:YAG laser. (c) End facet of the 220/200/100 0.22NA capillary fibre (d) Output intensity profile at 50W and (e) output intensity profile through a thin film polariser showing radial polarisation.

The Ho:YAG laser produced 50.1W of radial polarised output at 2090nm, limited by the laser cavity stability. At full operational power a pump absorption of 9.4dB with 49% optical-to-optical efficiency, and an average slope of 73% with respect to absorbed power was demonstrated. A polarisation extinction ratio of >120:1 was measured via introduction of a thin film polariser in the diagnostic arm, as measured with a Spiricon Pyrocam III. To the best of our knowledge this represents the highest power radially-polarised 2 µm laser reported to date.

## Example References

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