ALL SOLID STATE BLUE ROOM-TEMPERATURE THULIUM-DOPED UPCONVERSION FIBRE LASER

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Following the report by Grubb [1] we describe an all solid state, single wavelength pumped, cw, room temperature, upconversion laser which has operated in the blue between 475nm and 483nm or in the near infrared at 778nm. We have pumped this device at both longer and shorter wavelengths than those reported by Grubb. The system uses Yb-doped silica fibre to convert the output from a diode pumped Nd:YLF laser to a wavelength in the range 1.05μm to 1.18μm. This is used to pump a Tm-doped ZBLAN fibre giving rise to an upconversion process which involves the sequential absorption of three pump photons to populate the $^1G_4$ upper laser level as shown in Fig 1.

The Yb-doped silica fibre laser [2] is pumped by 1.2W of 1.047μm from a diode pumped Nd:YLF laser. The fibre used was 700ppm Yb-doped germano-silicate, the NA was 0.17 and the cutoff wavelength was 750nm. In a cavity with feedback provided by the Fresnel reflections from the bare fibre ends a slope efficiency, with respect to absorbed power, of 84% was recorded at 1.096μm. However, any particular lasing wavelength in the range 1.05μm to 1.18μm can be selected by the use of fibre gratings [3]. We have also used a flashlamp pumped Nd:YAG operating at 1.064μm as a pump source for the Yb obtaining 17% slope efficiency, with respect to incident power, in a cavity consisting of a high reflecting mirror and a fibre grating of 50% transmission at 1.128μm.

The fluorozirconate fibre used was supplied by Le Verre Fluoré and Tm-doped to 1000 ppm. The fibre NA was 0.21 and the cutoff wavelength was 800nm.

With the Yb laser it is possible excite blue emission from the Tm:ZBLAN fibre with a wide range of pump wavelengths. To investigate the upconversion efficiency of pumping in this range the tunable output from a singly resonant optical parametric oscillator [4] was launched into the Tm-doped fluorozirconate fibre. Fig 2 shows the variation of intensity of guided blue fluorescence as the OPO was tuned from 1.1μm to 1.2μm.

Blue lasing results exploring the short wavelength wing of the excitation spectrum have been obtained with pump wavelengths of 1.101μm, 1.112μm and 1.128μm. The lowest threshold achieved to date is 23mW of absorbed power (assuming 50% launch efficiency) for 1.128μm pumping. This was observed in 1.7m of fibre with mirrors highly reflecting in the blue butted to each end of the ZBLAN fibre; lasing was at 482nm. A typical characteristic for lasing at 479nm, using one highly reflecting mirror and a 37% transmitting output coupler, is shown in Fig 3. Again the pump wavelength was 1.128μm and the slope efficiency was 20% with respect to launched pump power. Using a beam analyser the blue laser output was found to be single spatial mode.

We also report the first observation of lasing at 778nm between $^1G_4$ and $^3H_5$ using a single wavelength pump at 1.128μm in Tm-doped ZBLAN fibre at room temperature. The laser resonator was formed by 1.7m of the LVF fibre and the Fresnel reflections from the bare fibre ends. A threshold of 180mW of incident pump power and a slope efficiency of 9% with respect to incident pump power was observed.

References

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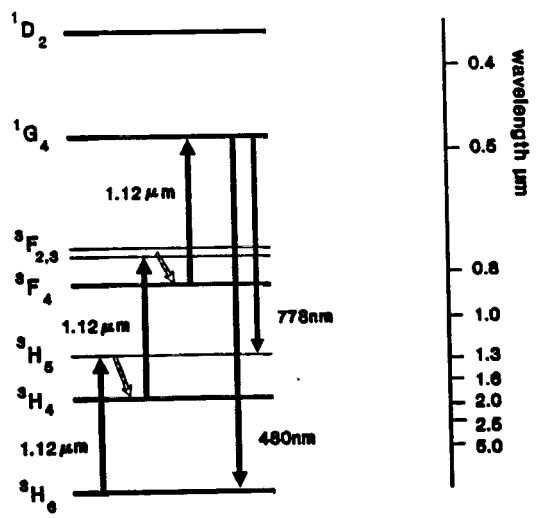

Fig 1 Energy level diagram for Tm showing upconversion scheme leading to lasing at 480nm or 778nm

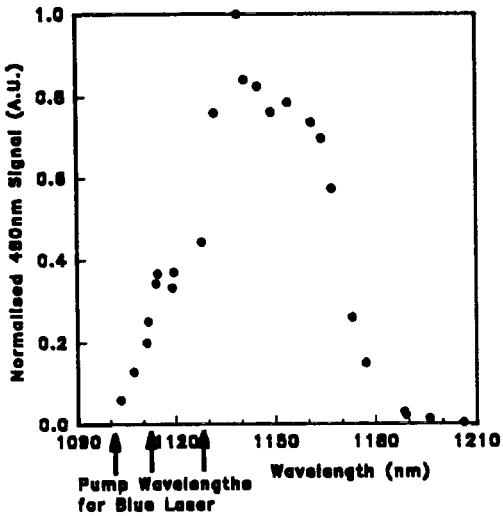

Fig 2 Excitation spectrum of $^1G_4$ to $^3H_6$ emission for Tm:ZBLAN fibre pumped with an OPO

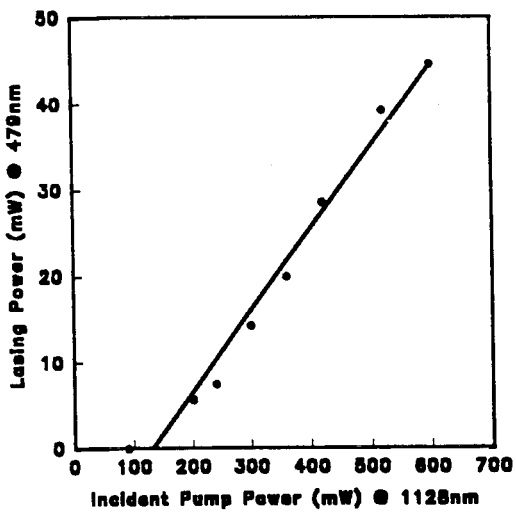

Fig 3 Lasing characteristic at 479nm for upconversion Tm:ZBLAN fibre laser