Recent progress in resonantly pumped holmium fibre lasers

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Abstract: Holmium-doped fibres enable the operation of silica fibre sources beyond 2.1 µm. We will discuss their applications and present recent results of resonantly core and cladding-pumped holmium fibre devices.

OCIS codes: (140.3460) Lasers; (140.3510) Lasers, fibre; (140.3070) Infrared and far-infrared lasers.

1. Introduction

Silica based fibre lasers have been demonstrated to operate across a wide spectral range by utilizing various rare-earth ions, most notably neodymium, ytterbium, erbium, thulium and holmium. Use of these active ions allows access to large portions of the 1-2 µm spectral region. A number of diverse fibre based sources using these rare-earth ions have been demonstrated which cover a range of temporal and spectral outputs that find utility across a wide range of applications; scientific, remote sensing, medical, defence and materials processing. Holmium doping enables the operation of silica fibre lasers in the 2.05- 2.2 µm spectral region with high efficiency and excellent beam quality and can potentially be realized in a monolithic, rugged form factor suitable for use in many of these applications. In particular holmium-doped silica based sources provide benefits in terms of atmospheric transmission and are of particular interest for remote sensing [1], and materials processing [2]. In addition to the new processing regimes that become available by operating at 2 µm, there are also significant eye-safety benefits which are a critical consideration for any industrial setting.

Resonantly pumped holmium fibre lasers leverage mature thulium fibre lasers as high power, high brightness monolithic pump sources. Cladding pumped holmium fibres use an all-glass double-clad structure to avoid absorptive losses associated with conventional polymer coatings. Although complicating fibre design and manufacture these fibres provide a reliable, robust platform for the development of scalable high power fibre lasers at 2 µm. In this fibre laser architecture the limitation of the reduced NA of an all-glass structure is compensated for by the high brightness of the thulium-doped silica fibre laser pump sources.

2. Tunable operation

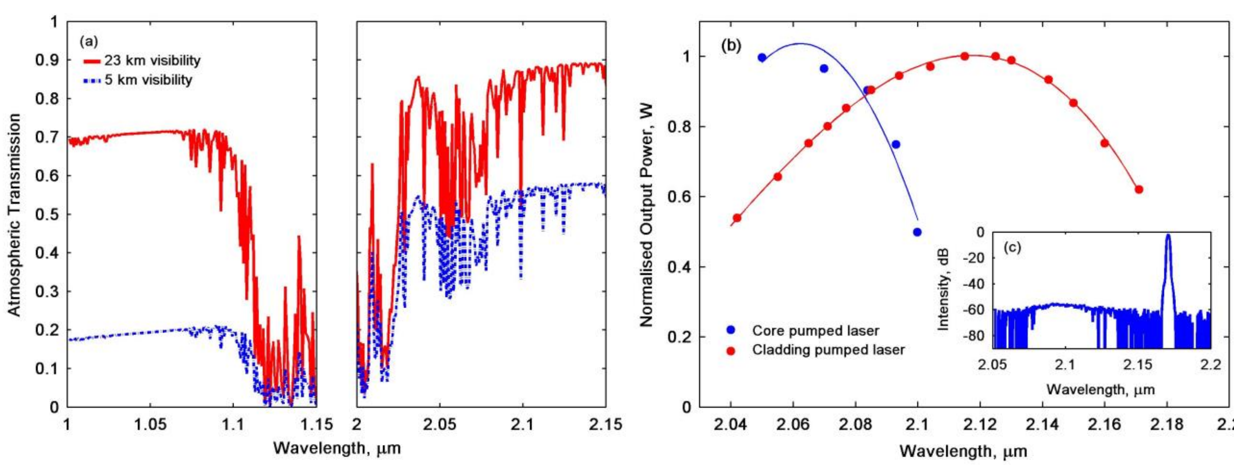

Figure 1. (a) ModTran atmospheric transmission around 1 and 2 µm. (b) Tuning ranges of free-space tunable core and cladding-pumped holmium-doped fibre lasers. (c) Output spectrum of the tunable cladding-pumped holmium-doped fibre laser at 2.17 µm.

The advantages of atmospheric transmission for wavelengths beyond 2.1 μm are evident in Figure 1(a). Beyond 2.1 μm the atmospheric transmission is high with a wide transmission window available. This is in comparison to the spectra around 1.9-2.05 μm typically accessible with thulium lasers, which is dominated by CO_2 absorption features. The transmission is also higher than that achievable with ytterbium fibre lasers at around 1 μm particularly in poor visibility conditions. For materials processing of plastics this spectral region also provides the ability to access a range of absorption resonances of various materials of interest [2].

We have used thulium fibre lasers to resonantly pump holmium fibre lasers and investigate the tunable operation of both core and cladding-pumped holmium-doped silica fibre lasers [3]. The spectral ranges accessible are shown in Figure 1(b). The core pumped laser operated from 2.04-2.1 μm and the cladding pumped laser covered the wavelength range from 2.04-2.17 μm. An output spectrum of the laser at 2.17 μm is shown in the inset illustrating the high spectral purity of the output even at this long wavelength.

3. High power resonantly pumped sources

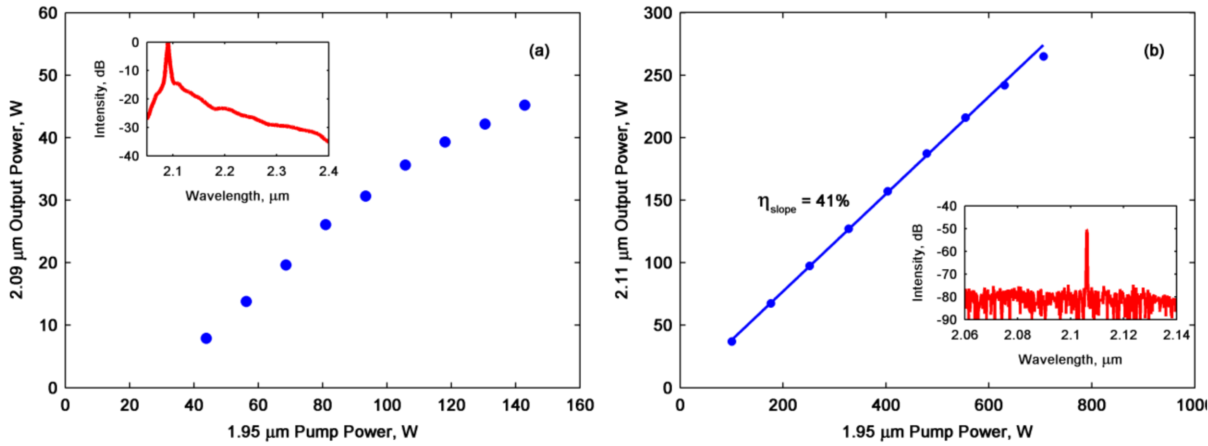

Figure 2. (a) Output power and typical spectrum from the pulsed PM holmium-doped fibre amplifier [4]. (b) Output power and spectrum of the CW resonantly pumped holmium amplifier [5].

Using the resonantly cladding pumped holmium-doped silica fibre architecture we have demonstrated high power pulsed [4] and CW amplifiers [5]. Results from these demonstrations are shown in Figure 2. In pulsed operation the free-space holmium fibre amplifier was able to achieve pulse energies of more than 2 mJ with an average output power of 45 W. The spectrum of the output showed significant broadening which is attributed to super-continuum generation initiated by modulation instability. The background ASE level was measured to be <100 mW.

In CW operation we have demonstrated more than 250 W of output power from a monolithic amplifier with no degradation in spectral quality from the master laser as shown in Figure 2(b). Improvements in beam quality and further power scaling are currently under investigation. In both cases the efficiency of these amplifiers is below the quantum efficiency associated with the resonantly pumped holmium laser transition. Further development of the fibre composition is underway to improve the efficiency of these systems.

4. Conclusions

Holmium-doped silica fibres present a fibre laser platform for increasing the wavelength range accessible by silica fibre lasers beyond 2.1 μm with high power, efficiency and excellent beam quality. We have fabricated a range of novel holmium-doped silica fibres and demonstrated both lasers and amplifiers based on resonant core and cladding pumping of these fibres with 1.95 μm thulium-doped silica fibre lasers. We have demonstrated high energy pulses with more than 2 mJ extracted from a polarization maintaining fibre and more than 250 W from a CW amplifier. With the maturation of fibre components and improved efficiency of the holmium fibre composition we anticipate the development of a range of pulsed and CW devices based on the resonantly pumped holmium fibres suitable for addressing a range of applications.

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6. References

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