Fibre Laser Systems for Marine Photonics

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Summary

We review recent progress on optical fibre lasers and discuss applications for them in the field of marine photonics. In particular we examine high efficiency schemes (electrical to green light) based around short pulsed lasers and novel poled materials. Such light sources could find novel applications in underwater autonomous vehicles.

Introduction

Traditionally fibre laser based systems have found little applications in the deep oceans, despite their many advantages such as high efficiency, compactness, flexibility etc. Of course the main reason for this the high absorption of sea-water at the lasing wavelengths (typically 1.06 μm or 1.55 μm). However the rise of high power frequency doubled fibre laser systems operating near 530 nm makes such sources increasingly attractive for marine photonics applications. More recently the development of new wavelength sources such as a 900nm Neodymium fibre laser are ideal since when frequency doubled operate near the maximum transparency wavelength for sea-water[1].

Possible Laser Systems

Fibre lasers typically incorporate a rare-earth dopant which provides the lasing medium and typical choices are Erbium, Ytterbium, while Neodymium and Thulium are less common choices. A major advantage of fibre lasers is their high efficiency with both Yb and Nd fibre lasers have optical efficiencies about 70% when pumped by diodes. Since optical diodes are also extremely efficient the electrical-to-optical efficiency can be above 40% for well designed systems. This is particular important for systems based on underwater autonomous vehicles (UAVs) where the available electrical power is limited and so the more efficient a system the better. Then once the light has been generated the next stage is to frequency double the light to the green or blue. Again using advanced nonlinear crystals this can be done with a conversion efficiency of $\sim 50\%$ depending on the peak power and bandwidth. This gives a total electrical-to-blue light conversion efficiency of between 10% and 20% depending on the precise laser system being used. Thus for 20 Watts of electrical power, between 1 and 2 Watts of blue light could be achieved.

For example within the ORC researchers have generated 45 Watts of green light using 20ps pulses at Megahertz repetition rates[2] with high electrical to optical conversion efficiency. While other researchers have demonstrated a femtosecond Nd doped fibre laser operating between

890nm and 910nm[3]. Such a source could be efficiently doubled using a well designed periodically poled crystal or by using Type II phase-matching in BBO. Although not demonstrated it should be possible to scale the power of the Nd doped system by using several amplifiers in a chirped pulse configuration to ensure multi-watt output.

For UAV applications a crucial consideration is whether or not the systems need to be contained within pressure vessels which adds considerable cost and bulk to any system. For the Yb system the fibre should withstand deep-ocean pressures with ease (trans-Atlantic optical cables operate with no problems) and so are ideally suited for deep-water applications. In contrast the Nd system would require modification to remove the diffraction grating pair, and here photonic crystal fibres with anomalous dispersion could be used.

Discussion

We have reviewed possible fibre laser systems for UAVs operating in the deep ocean, and shown that high efficiency, blue/green light generation is practical with 10s of Watts of electrical power. The small size and flexible nature of fibre laser sources makes them ideal for UAV applications when operating in the deep ocean. The possible applications of such sources are varied and include, micro bathymetry, remote sensing, LIDAR applications etc. For example using short pulse LIDAR it would be possible to obtain cm resolution for bathymetry applications over long distances in clear water while optical tomography techniques would improve the resolution in highly scattering situations. For remote sensing, Raman techniques would allow direct measurements of the water temperature while detection of fluorescence would allow identification of particle type and quantity. Hence we believe that the inclusion of fibre lasers in the next generation of UAVs could dramatically improve their data collection abilities.

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