High power fibre lasers based on point-by-point inscribed fibre-Bragg gratings

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Abstract: We report on a novel approach to realise high power continuous-wave fibre lasers utilising femtosecond laser point-by-point inscription of fibre-Bragg gratings. The lasers feature highly narrow linewidths and polarised outputs, perfectly suited for frequency conversion.

Introduction
The availability of high brightness continuous-wave (cw) radiation in the visible with power levels from as low as a few milliWatts up to tens or even hundreds of Watts is crucial for a wide range of applications. These lay mainly in the fields of medicine and defence but are as diverse as micromachining, sensing and Ti:Sapphire pumping. Due to their unique properties like high compactness and robustness as well as inherent diffraction limited beam qualities, fibre based laser sources have gained enormous interest in recent years. Since their emission peak is typically located in the near infrared, nonlinear frequency conversion has to be employed in order to access the visible spectral range. In contrast to pulsed laser sources, the fundamental peak power is low in continuous-wave lasers, thus very long nonlinear crystals have to be used in order to achieve practical conversion efficiencies. As this is fundamentally linked to a very narrow phase matching bandwidth, the main requirement on the fibre laser is a highly narrow and stable linewidth.

Experiment
In contrast to other successful but rather complex schemes [1], in this paper we demonstrate a very simple and scaleable approach to tackle this challenge. Based on the technique of using femtosecond laser pulses at kHz repetition rate to inscribe fibre-Bragg gratings (FBGs) in single-mode fibres [2] we fabricate a highly frequency sensitive cavity end mirror inside the core of a double-clad Yb-doped laser fibre. We show that by pumping the fibre with a high-power laser diode and exploiting Fresnel-reflection for output coupling, an extremely compact laser source can be realised. The resulting laser linewidth can be as small as only a few picometers at output power levels in the multiple-Watt range or even higher. We will discuss a unique property of this laser, namely the fact that an increasing temperature gradient within the fibre can lead to a small but linear increase in linewidth. As the bandwidth requirements are more relaxed at higher peak power levels, this makes it possible to realise a fibre laser which is not ultimately limited in power by the onset of stimulated Brillouin scattering (SBS) while still narrowband enough to ensure efficient frequency conversion.

Due to the asymmetric shape of the regions where the fibres refractive index has been modified by the femtosecond laser, the FBG exhibits a stronger interaction with electric field components which are linearly polarised in a specific direction. We will present studies of the factors influencing the fibre laser’s degree of polarisation and will also present our second harmonic generation (SHG) results obtained by using periodically poled nonlinear crystals to convert the output of the fibre laser.

Because the the small region within the gain fibre, where the actual FBG is inscribed dictates the overall properties of the laser, we will show that simple passive temperature control of a few mm long fiber section is sufficient to achieve excellent long term stability of the lasers output parameter like power and wavelength.

References