1.65μm long range distributed testing of optical fibres using a compact Q-switched fibre laser

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Abstract: A simple Q-switched Erbium-doped fibre laser operating at 1.5μm forms the basis of a high peak power pulsed source at 1.65μm. Applications include monitoring of active telecommunication links, loss measurement at 1.65μm and distributed temperature sensing.

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High power pulsed sources operating at 1.65μm allow active monitoring of existing telecommunication links operating at around 1.5μm. They are also becoming increasingly important for characterising losses at the higher wavelengths of extended bandwidth systems designed around the L-band Erbium-doped fibre amplifiers.

A compact design based on Raman shifting the output of a Q-switched fibre laser operating at 1.5μm is described. It is first demonstrated as a source for a 1.65μm OTDR measurement and then as a source for a 1.65μm Raman-based distributed temperature sensor, in contrast to distributed temperature sensors normally operating at 1.5μm [1,2].

Fig. 1 illustrates the experimental setup used for generating a 1.65μm pulsed source. It consists of a Q-switched Erbium-doped fibre laser coupled with a 390m length of conventional silica fibre. A fibre Sagnac loop mirror (reflectivity = 19%) forms one of the cavity mirrors and is spliced to a WDM and a length of Erbium-doped fibre. The output from the Erbium-doped fibre end was focused through an acousto-optic modulator (AOM) onto a plane mirror (99% reflecting at 1.55μm). The laser operating at 1.5μm produces pulses of up to 100W of peak power and a duration of 33.5ns for repetition rates of less than 1kHz. By the process of stimulated Raman scattering, pulses at a wavelength of 1.65μm are generated along the 390m of fibre. The generated 1.65μm pulses are separated from the residual 1.5μm pump pulses by a band-pass filter centred at 1.65μm, to produce pulses with 1.5W of peak power and 40ns pulse width. The broadband nature (25nm) of these pulses are ideal for OTDR as coherent effects are reduced to a minimum.

Fig. 1. Experimental setup for generating high peak power 1.65μm pulse
In addition to using the 1.65\,\mu m pulsed source for active monitoring of transmission lines operating at a different wavelength, OTDR measurements at 1.65\,\mu m provide more accurate determination of macro and micro-bend losses than at 1.5\,\mu m. Fig. 2 shows the Rayleigh backscattered signal, clearly illustrating its capability of performing attenuation and splice loss measurements at the wavelength of 1.65\,\mu m for the length of test fibre. The 1.65\,\mu m source has also been used for distributed temperature measurements based on monitoring the anti-Stokes Raman signal at 1.5\,\mu m. The measurement was made over a sensing range of 10.1\,km, consisting of 4 drums of conventional single mode silica fibre spliced together, with lengths of 8.6\,km, 0.5\,km, 0.5\,km and 0.5\,km, with the third drum (0.5\,km) heated to a temperature of to 59\,°C from the room temperature of 23\,°C. To accurately predict temperature changes the Raman signal has to be referenced to the temperature-independent Rayleigh signal. The ratio of the Rayleigh and Raman signals provides a temperature dependent signal which is independent of splice/bend losses and corrected for fibre attenuation. Fig. 3 shows this ratio for the last three sections of test fibres. The temperature resolution was calculated to be 4\,°C, for a sensing range of 10.1\,km and spatial resolution of 10m. Using the Raman anti-Stokes temperature sensitivity of 0.8\,%\,K\,^{-1} [3], the temperature change was calculated to be 36K, and this was in agreement with the measured fibre temperature change.

Fig. 2. Backscattered Rayleigh signal using a 1.65\,\mu m pulsed source

Fig. 3. Ratio of Raman to Rayleigh backscattered signal, illustrating the temperature rise of 40\,°C and 4\,°C temperature resolution