

# **Multiwavelength Operation of Brillouin/Erbium Fibre Lasers With Injection Locked Seeding**

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## **Abstract**

We describe a regime of operation of a Brillouin/Erbium fibre laser which can produce laser combs with 10GHz or 20GHz spacings. Over 10 lines have been produced in a single laser with injection locked seeding.

Brillouin/Erbium Fibre Lasers (BEFL) have recently been demonstrated as a novel mode of operation of fibre lasers, using both the gain of an erbium doped fibre (EDF) and Brillouin gain in single-mode optical fibre.<sup>1</sup> BEFLs can be configured to produce laser combs, with potential applications in dense wavelength division multiplexing.<sup>2</sup> In this paper we present a different regime of operation of a BEFL, in which a signal is injection locked in a ring resonator, and which then seeds the BEFL modes.

The laser configuration is shown in Figure 1. In comparison to the previously reported BEFL,<sup>2</sup> this resonator contains no isolator. Without an injected narrow linewidth signal, the ring resonator operated as a bi-directional erbium-doped ring laser (EDRL). Injection of the signal through the 3dB coupler, with sufficient power and close in wavelength to the free-running wavelength of the EDRL, forced the operation of the ring to be injection locked, in the process forcing some suppression of the gain in the EDF. Operation was then uni-directional, in the counter-clockwise (CCW) direction of Figure 1.

The power in the injection-locked signal increased with increasing 1480nm pump power, until sufficient Brillouin gain was generated in the clockwise (CW) direction. The Brillouin gain was generated at a frequency downshifted 10.8GHz from and in the opposite direction to the injection locked signal.<sup>3</sup> If the combination of the Brillouin gain and the EDF gain was such that it equalled the resonator losses, BEFL operation commenced in the CW direction. Increasing the power in the signal would seed another signal in the CCW direction, cascading the process. In each direction a 21.6GHz laser comb was generated, the combination of the two directions giving a 10.8GHz comb, as shown in Figure 2, taken from the 10% coupler. Measurement conditions for Figure 2 were 60mW launched 1480nm power and 1.8mW launched injected signal. In comparison to previous schemes,<sup>2</sup> in which each line was a BEFL line, in this arrangement the first line is injection locked and subsequent lines are BEFL lines.

The laser output contains multiple wavelengths, each operating in only a single direction, and hence spatial holeburning does not occur. This property, and the characteristic that each line stimulates a different Brillouin gain component, allows narrow linewidth operation in each line, and a narrow lasing line spacing in the EDF at room temperature. The signals in each

direction are at different frequencies, a property which may be useful in gyroscope applications.<sup>4</sup> The resonator geometry for multiline operation is simple, and is similar to multiline generation in a Brillouin fibre laser,<sup>5</sup> except for the inclusion of the EDF.

For a given 1480nm pump power, there is an optimum power for the injected signal to achieve the maximum number of generated lines. As the total output power is shared between the lines, if the injected power is too large, it will generate a large Brillouin gain, with substantial suppression of the EDF gain. The BEFL lines then require large power to seed an additional line, and the total number of lines is reduced. If the injected signal is too small, the Brillouin gain will be correspondingly small, and competition occurs with the free-running EDRL operation, again limiting the number of lines. In our results the number of lines is limited by the power available from the 1480nm pump diode.

In conclusion we have demonstrated a new regime of operation of a BEFL, with operation seeded by an injection locked signal. In this configuration, 10GHz and 20GHz optical combs can be generated, and generation of over 10 lines has been demonstrated.

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Figure Captions:

Figure 1. Schematic of Brillouin/Erbium Fibre Laser with injection locked seeding.

Figure 2. Optical comb generated by the BEFL, combining the CW and CCW signals.  
Arrowheads indicate the direction of each signal in the resonator, whether CW or CCW.



