# Twisted Hi-Bi Fiber DFB Lasers with Controllable Output Polarization

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**Abstract:** We demonstrate that single polarization, hi-bi fiber DFB lasers are in general characterized by elliptical state of polarization, due to the in-built fiber birefringence axis rotation. Externally applied birefringence-axis twist is shown to provide accurate control of the output SOP. Continuous tuning from circular to linear polarization, with PER of ~40dB has been demonstrated.
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## 1. Introduction

Fiber DFB lasers [1] exhibit a number of advanced performance characteristics, such as kHz-range linewidth, single polarization, extremely low RIN, and phase noise [1]. In addition, advanced designs enable unidirectional output, low pump threshold, very high side-mode suppression and high efficiency [3][4]. Due to the combination of these properties and characteristics, they are proving increasingly important devices in the field of optical sensing. With the advent of coherent optical communications, they are also promising candidates for optical sources in advanced optical communication systems. Multi-wavelength fiber DFB lasers [5] and laser arrays with pump redundancy have also been demonstrated [6].

The output polarization of fiber DFB lasers can be influenced by a number of parameters [7][8]. Single polarization operation has been achieved by a number of techniques, such as twisting ordinary low-bi fibers [9], or controlled UV exposure resulting in polarization-dependent phase shift and/or grating strength [10]. In most applications, single polarization DFB lasers are required to be subsequently spliced to hi-bi passive fibers in order to maintain polarization. Birefringent axes in hi-bi fibers, on the other hand, are known to rotate along the fiber length [11], with different rotation rates. The effect on the output of high performance fiber DFB lasers has not been addressed. In this paper, we show that single-mode, single-polarization fiber DFB lasers, written directly in active hi-bi fibers, exhibit elliptical polarization output. We also show that externally-induced birefringence-axes twist can be used to manipulate and control accurately the output state of polarization.

## 2. Twisted Hi-Bi Fiber DFB Lasers

A number of fiber DBF lasers were fabricated using different hi-bi, Er-Yb doped fibers. Typically 5cm long asymmetric fiber DFB lasers were fabricated [3], using a continuous grating writing technique. The DFBs were pumped by a 980nm single mode laser diode with typical slope efficiencies of ~25% (wrt absorbed power). Single-mode, single-polarization and narrow linewidth (<30kHz) output around 1550nm have been fabricated. OSNR as high as 60dB was achieved while the laser RIN was <–147dB/Hz for RF frequencies above 5MHz.

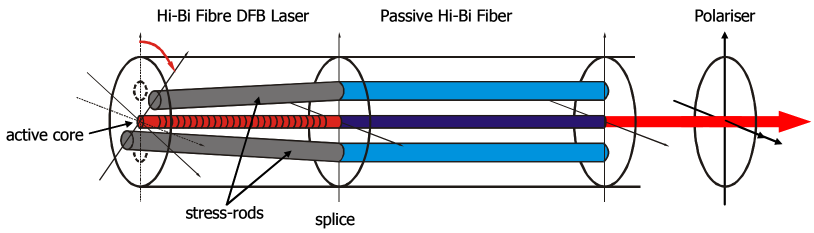


**Figure 1:** Hi-Bi fiber DFB laser schematic (co-pumped - pumping fiber not shown for clarity).

Figure 1 shows the schematic of hi-bi fiber DFB laser, spliced to a matching passive hi-bi fiber. The passive fiber was angle-cleaved to minimize back-reflections. A high extinction ratio polarizer was used at the pigtailed output in order to measure the polarization extinction ratio of the collimated laser output. The polarization extinction ratio is defined as the max/min throughput power ratio (in dB), corresponding to two orthogonal polarizer orientations.

The active hi-bi fiber under test was measured to have an average internal axis twist of ~ +6 °/cm. Figure 2(a) shows the output polarization extinction ratio (PER) as a function of applied DFB fiber external twist. Without any external twist, the PER was ~10dB, which corresponds to an elliptical SOP. For twist rates of about -10 to -12 °/cm the output SOP became linear, with max PER of ~35dB. It is worth noting that the external twist required to achieve maximum PER is about 2 times the internal one. This is probably required in order to counteract the effect of the extra twist-induced stresses in addition to the initial geometrical twist. For opposite external twist rates of about +12 °/cm the PER was ~0dB, which corresponds to circular output SOP. For larger external twists, the PER is shown to increase again. Similar behavior was observed with different active hi-bi fibers showing different rates of internal axis twist. Figure 2(b) shows the peak output PER as a function of active/passive hi-bi fiber misalignment splice angle (left axis) and the external twist applied to achieve it (right axis). Also shown is the theoretically expected PER given by $\tan^2(\theta)$, where θ is the misalignment splice angle (blue line) showing very good agreement. It is shown that in order to maintain the external twist-induced high PER, the active/passive hi-bi fiber misalignment angle should be kept below ±0.5deg.

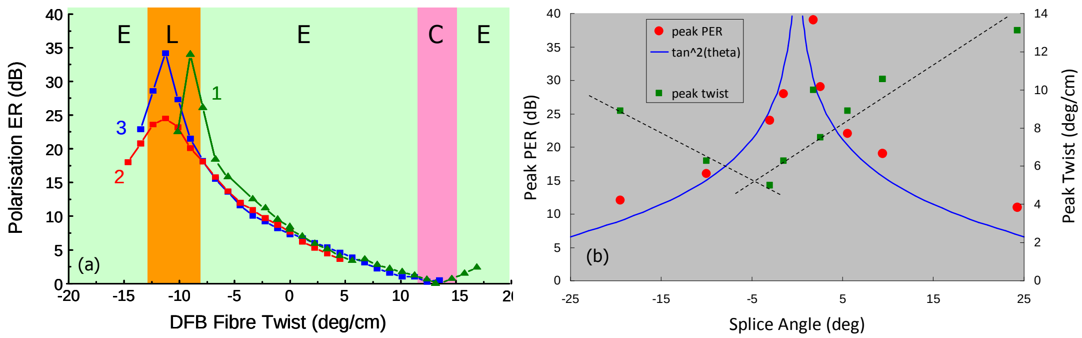


**Figure 2:** (a) PER as a function of DFB fibre twist (L: linear, E: elliptical and C: circular SOP), (b) peak PER as a function of active/passive hi-bi fiber misalignment splice angle (left axis) and external twist required to achieve it (right axis).

To confirm that these effects are primarily due to the active fiber inherent twist, the hi-bi fiber DFB lasers were also tested without the spliced passive hi-bi fiber, showing similar output polarization effects with the applied external fiber twisting. It was also observed that externally-twisted DFB lasers with linear polarization output were more susceptible to residual external feedback. DFB lasers with elliptical polarization output, on the other hand, showed remarkable tolerance to external backreflections. Additional results obtained with different fibers and testing arrangements, as well as, the polarization stability in the presence of external back-reflections will be further discussed at the conference.

## 3. Summary - Conclusions

We have demonstrated that single polarization, hi-bi fiber DFB lasers are in general characterized by elliptical state of polarization, due to the in-built fiber birefringence axis rotation. We have also shown that additional external axis twisting can be used to accurately control the output state of polarization in such lasers. This is important when hi-bi fiber DFB lasers are spliced to matching passive hi-bi fibers, in order to maintain and deliver stable linear polarization. It is shown that any state, ranging from linear to circular, can be achieved. Stable linear polarization with PER close to the theoretical limit of ~40dB [12] has been demonstrated. The results of Fig. 2(a) show that twisted hi-bi fiber DFB lasers can be potentially used as optical twist sensors.

## 4. References


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