All-Fiber Filters for the Design of Tandem-Pumped Fiber Lasers

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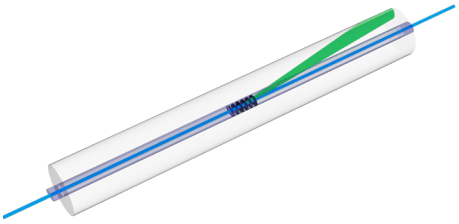
Tandem pumping offers several advantages in the context of high-power single-mode fiber lasers, making it a valuable technique in various applications. However, designing a tandem-pumped fiber laser is quite challenging as we will see in this application note.

Introduction

In 2009, IPG Photonics achieved a groundbreaking accomplishment by demonstrating a 10 kW nearly single-mode fiber laser through a tandem-pumping configuration. Tandem pumping is recognized as one of the most promising techniques for enhancing the output power of single-mode fiber lasers operating at 1µm. This approach holds significant relevance for applications in the defense sector, like Directed Energy Weapons (DEW), as well as industrial applications such as cutting and welding, where the demand for very high-power fiber lasers exceeding 30 or 40 kW is growing.

Tandem-pumped fiber lasers at 1 micron

Tandem pumping involves the utilization of multiple pump sources at different wavelengths to efficiently stimulate the gain medium within the fiber. A common configuration of tandem-pumped ytterbium (Yb)-doped fiber lasers uses fiber lasers emitting at 1018 nm and pumped at 976 nm which in turn pumps a Yb fiber laser typically operating at 1070 nm or 1080 nm, as shown in Figure 1.



However, designing tandem-pumped fiber lasers poses substantial challenges. Tandem-pumped 1-micron fiber lasers typically utilize forward pumping. At the 1018 nm wavelength, low absorption requires a longer active fiber length and larger core diameter, resulting in increased nonlinear effects.

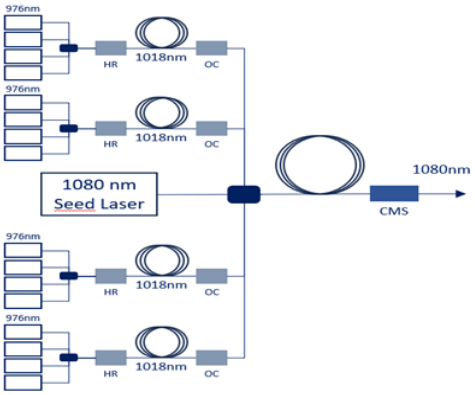


Figure 1: Typical tandem-pumped fiber laser at 1 micron

While a backward-pumping configuration proves advantageous in reducing non-linear effects like SRS and TMI, it introduces a new challenge. Sending the 1080 nm laser signal backward from the power amplifier can harm the performance of the 1018 nm fiber lasers.

Therefore, a critical aspect involves preventing the backward propagating 1080 nm laser signal from returning into the 1018 nm fiber lasers. This counter-propagating signal can adversely affect the operation of the 1018 nm fiber laser. While high-power isolators or filters could be employed, these solutions tend to be either prohibitively expensive or not commercially available. We will see below how to address this issue using an all-fiber FBG-based notch filter.

FBG-based notch filters for tandem-pumped fiber lasers

indie has recently introduced the WSF, an all-fiber notch filter. The WSF is advantageously used to filter out the 1080 nm back-propagating laser signal as illustrated in Figure 2. The WSF is spliced at the output of the 1018 nm fiber laser and cleverly guides the unwanted 1080 nm signal into the cladding of the fiber where it can be safely extracted.

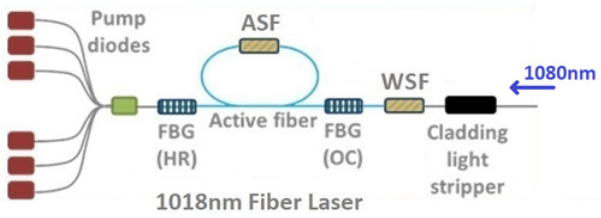


Figure 2: FBG-based filters for 1018 nm fiber laser

A typical transmission spectrum of a WSF for use in a 1080 nm tandem-pumped fiber laser is illustrated in Figure 3 below.

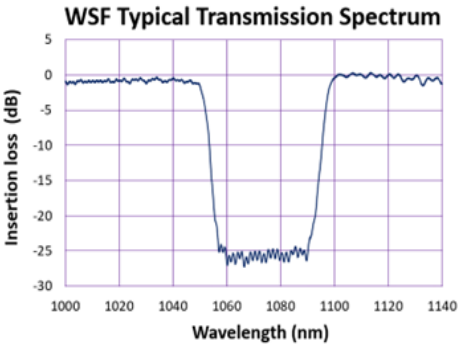


Figure 3: WSF typical transmission spectrum

The WSF features several advantages such as high-power handling, low insertion losses, high stopband attenuation, and in-line configuration (no circulator needed). The WSF simplifies the design process of tandem-pumped fiber lasers and substantially improves their overall performance and reliability.

Conclusion

Tandem-pumped fiber lasers at 1 micron provide an attractive solution for power scaling of single-mode fiber lasers. However, the design of such tandem-pumped fiber laser involves considerable challenges. indie has recently introduced the WSF, an all-fiber notch filter to improve tandem-pumped fiber laser performances. The WSF also finds other uses in such applications as Raman spectroscopy, fluorescence imaging, or other multi-wavelength laser systems.