Studies of the Optical Bandwidth of a 25 W 2 μm Band PM Hybrid Ho-/Tm-Doped Fiber Amplifier

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At the time of this research, Clement Romano was with [a] and [b]. He is now with [c].

1). Introduction. New developments in LIDAR and atmospheric sensing experiments highlight the need for studies of the optical bandwidth and wavelength dependence of multi-watt, large bandwidth, high dynamic range polarization-maintaining optical amplifiers in the 2—2.1 μm band. Recently we have demonstrated a hybrid single clad-double clad Tm-doped fiber amplifier with greater than 20 W output and a dynamic range of >20 dB in the 2 μm band [1,2], and a >25W output PM hybrid HDFA/TDFA with a dynamic range of 34 dB [3]. Both demonstrations were carried out at a single input wavelength of 2051 nm. In this paper we extend our experimental studies to the signal wavelength dependence of a PM hybrid HDFA/TDFA with a single clad Ho-doped preamplifier [4-7] and a double clad Tm-doped power amplifier. We have studied the performance of the amplifier from 2004 to 2108 nm, and in this paper, we report first experimental results for this wavelength region. We find that our hybrid Ho-Tm-doped design provides a PM fiber amplifier with a combination of large output optical signal-to-noise ratio, broad operating bandwidth, and high P_{out} of 28.5 W at λ_s = 2069 nm.

2) Experimental Setup. The optical design of our hybrid PM HDFA/TDFA is shown in Figure 1. A single frequency input signal is coupled into a preamplifier consisting of two stages, F1 (3.0 m) and F2 (2.0 m) of PM Ho-doped fiber, IXBlue IXF-HDF-PM-8-125. Output from a multi-watt fiber laser P1 at 1941 nm is split by coupler C1 (30%/70%) and is sent to both F1 and F2 via the WDMs. The preamplifier output provides the signal input to power amplifier F3, a 6.0 m length of double clad PM Tm-doped fiber (IXBlue IXF-2CF-Tm-PM-10-130). Two multimode multi-watt 793 nm laser sources are coupled into F3 by means of the 2x1 pump

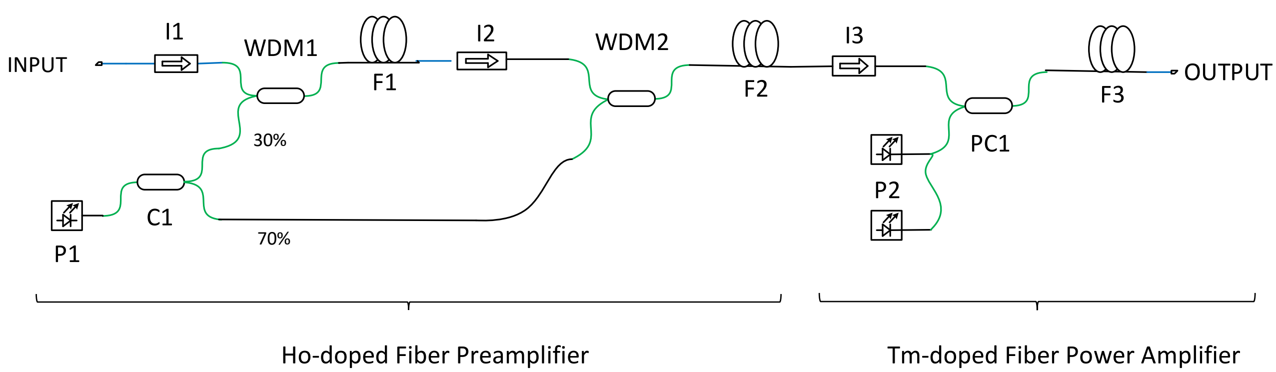

Figure 1. Optical Design of Three Stage Hybrid PM HDFA/TDFA

combiner PC1. The total pump power at 1941 nm coupled into F1 and F2 is designated P_{P1}, and the total pump power at 793 nm coupled into F3 is designated P_{P2}. In our measurements, input signal power is designated as P_s and output signal power as P_{out}. P_s is measured at the input of F1 and P_{out} is measured at the output of F3. PM signal light propagates though the fibers and components in the amplifier on the slow fiber axis.

3). Experimental Results Figure 2 shows the measured P_{out} as a function of P_{P2} for several values of P_s at 2069 nm . The measured values of P_{out} vary linearly with P_{P2}, and a maximum optical-optical slope efficiency of η = 53 % is observed at the maximum input signal power P_s = 0 dBm. The maximum signal output power achieved with this amplifier is 28.5 W, for P_{P1} = 4.6 W @ 1941 nm and P_{P2} = 53.6 W @ 793 nm.

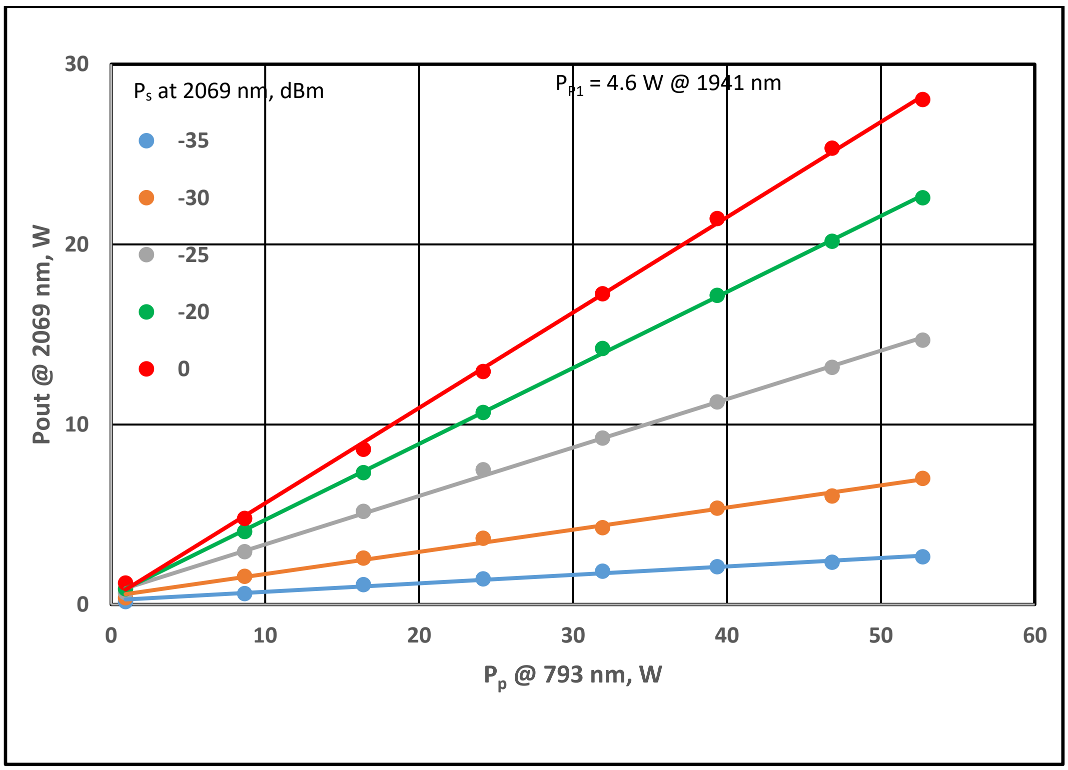

Figure 2. P_{out} vs. second stage pump power P_{P2} for different signal input powers P_s at 2069 nm

Values of gain G and noise figure NF for the amplifier are plotted below in Figure 3 as a function of signal wavelength λ_s. We observe that the maximum small signal gain of 70.7 dB is achieved at 2051 nm, and that G remains above 60 dB for a wavelength range of 2016—2090 nm. The noise figure reaches its experimental minimum of 7.2 dB at 2075 nm and increases from this point both with increasing and decreasing signal wavelength. The relatively large value of NF = 24.3 dB and the relatively small value of G = 43.5 dB at 2004 nm are attributed to increasing absorption at shorter wavelengths in the PM Ho-doped preamplifier stage [6,7].

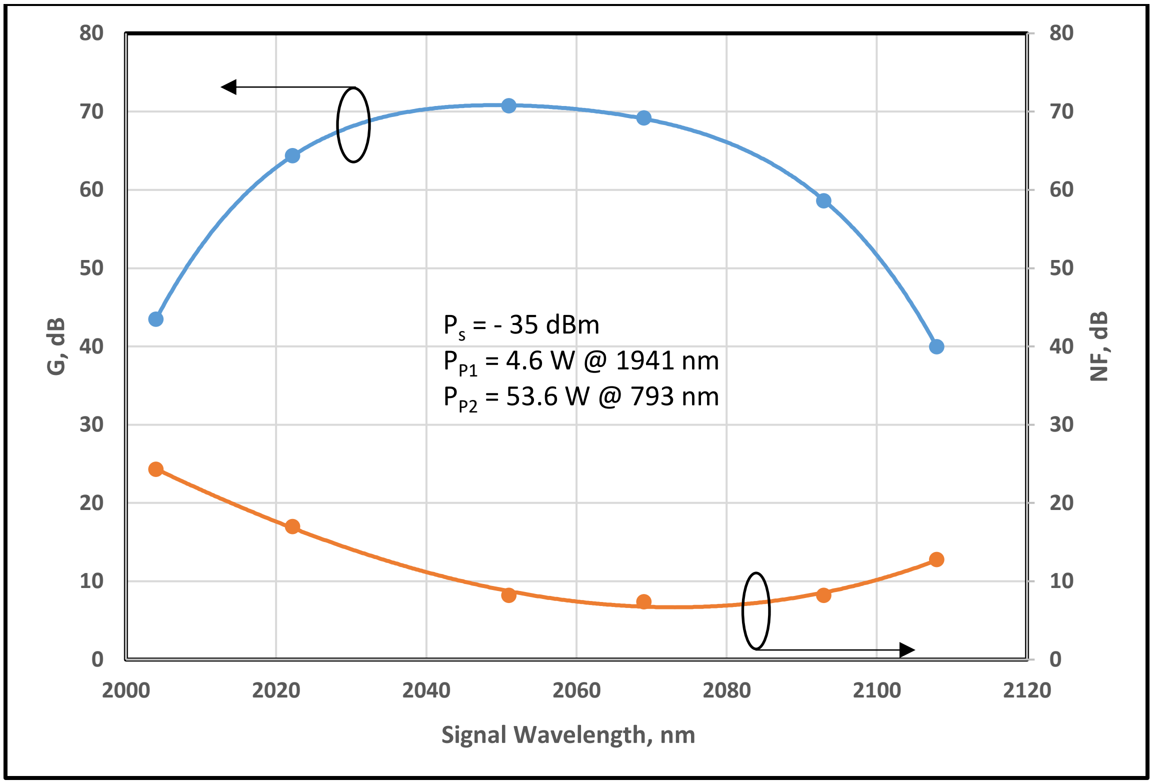

Figure 3. Experimental Gain G and Noise Figure NF vs. Signal Wavelength

In addition to the data in Figures 2 and 3, measurements of saturated output power vs. signal wavelength, optical signal to noise ratio, output spectral performance of the amplifier, and slope efficiency vs. signal wavelength will be presented in detail at the conference.

4). Summary We have demonstrated the architecture and performance of a hybrid PM HDFA/TDFA over a wide range of signal input wavelengths from 2004—2108 nm. With this amplifier, we achieved a maximum output power of 28.5 W, a maximum small signal gain of 70.8 dB, and a minimum noise figure of 7.2 dB. Our measurements of the wavelength dependence of the spectra and output power yield a 3 dB operating bandwidth of the hybrid amplifier of 93 nm (2008—2101 nm). The maximum observed OSNR was 51.4 dB/0.1 nm at 2093 nm.

Our novel amplifier design points the way toward future applications requiring compact, efficient, high gain, and high output power fiber amplifiers in the important 2000-2150 nm region of the spectrum.

5). References

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