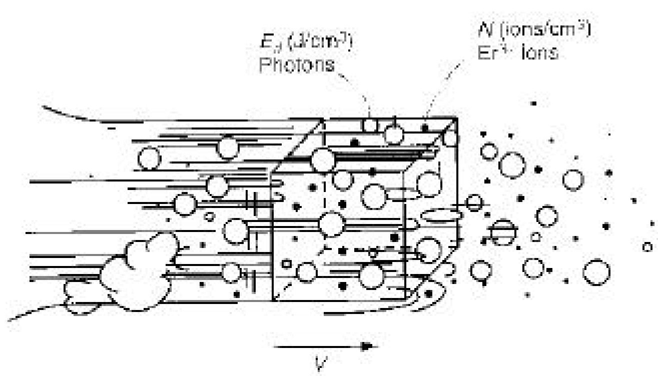
ECE1640H

Advanced Labs for Special Topics in Photonics

LABORATORY INSTRUCTION NOTES

ERBIUM-DOPED FIBER AMPLIFIER



Fictitious moving pill box in a fiber amplifier

Faculty of Applied Science and Engineering
University of Toronto
Canada

Keigo Iizuka

Revised April 2003

Introduction

The erbium-doped fiber amplifier EDFA has made tremendous progress since its invention in 1986. The optical amplifier has replaced the rather involved process of the fiber optic repeater station. It created a revolution in long distance optical communication systems. Simplicity and reliability of the repeater compartment are especially important when the optical fiber cable is used as a submarine cable. We are going to revisit the cutting edge of this important discovery in the field of fiber optic communication.

PRECAUTIONS

1. Use extreme care in handling the fiber. Breaks create unexpected exposure to the high intensity light power. Wear goggles whenever the layouts are changed.
2. Protect your eyes against the **invisible** high-intensity light power. No provisions have been made to protect against careless handling.

Purpose

There are two major purposes to these investigations:

1. Experimental studies of the properties of the erbium doped fiber amplifier (EDFA).
2. Construction of a fiber laser out of the EDFA.

Fiber amplifier

We will experimentally investigate the following properties of the EDFA:

1. Bandwidth of the amplified spontaneous emission noise (ASE noise).
2. Threshold pump power.
3. Conversion efficiency.
4. Stimulated emission cross-section.

Fiber laser

We will construct an erbium-doped fiber laser out of a fiber amplifier by creating feedback from the output into the input power of the fiber amplifier. We will investigate the stability of oscillation of such a fiber laser.

Preparation

Read the operation manual of the optical spectral analyzer (OSA). Read Chapter 13 “Optical Amplifiers” (pp. 833-892) of *Elements of Photonics* Vol. 2 for the fiber amplifier and Chapter 14 “Transmitters” (pp. 1004-1013) of the same book for the erbium-doped fiber laser.

Experiments

1. ASE Noise Spectrum Measurement

i) Turn on the OSA and set the wavelength range between 1.520 and 1.580 ìm. Connect as shown in Fig. 1.

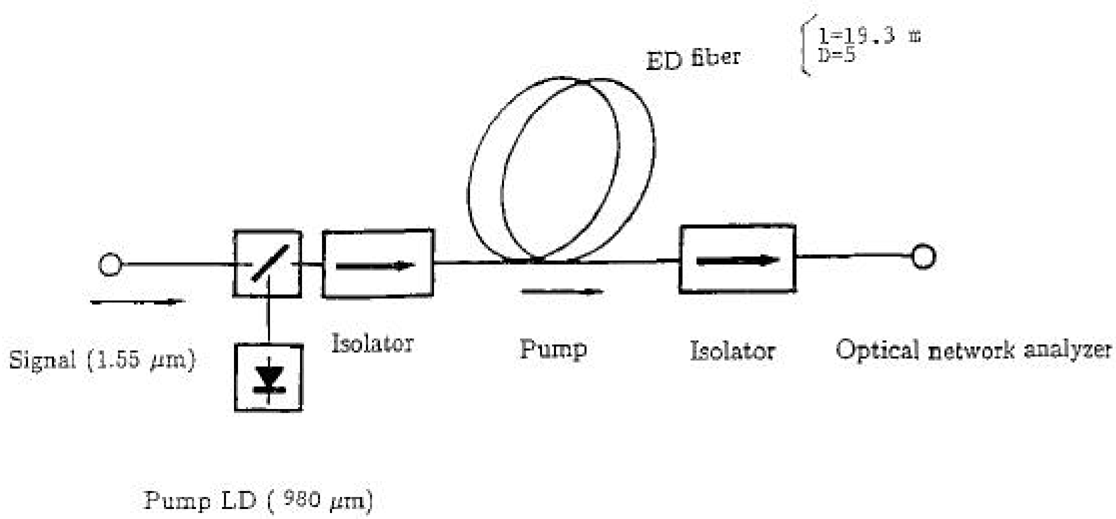


Fig. 1: Block diagram of an EDFA.

ii) Turn on the pump power only. Set the pump laser current at I_p = 1.75 mA, which corresponds to p_{pump} = 80.3 mW. Do not exceed 195 mA.

iii) Display without an input signal. This is amplified spontaneous emission noise (ASE) as shown in Fig. 13.19 on p. 869 of *Elements of Photonics,* Vol. 2.

iv) Assuming the spectrum of the spontaneous emission is independent of wavelength, as shown in Fig. 13.20 on p. 870, determine the half power full width (HPFW) gain bandwidth of the EDFA. Express it in terms of wavelength as well as in frequency.

2. Threshold Pump Power P_p^{th}

i) Set the input signal power P_s = -29.4 dBm at ë$_s$ = 1.55 ìm. Find how the gain of the EDFA changes as a function of the pump power. Plot the amplifier gain as a function of the pump power as shown in Fig. 13.10(b) on p. 857 in *Elements of Photonics*.

ii) Determine the value of P_p^{th} from the plotted graph.

iii) Repeat with input power P_s = -8.3 dBm. Verify that the value of P_p^{th} is independent of P_s.

iv) Calculate the expected threshold pump power P_p^{th} and compare with the obtained results.

What assumptions did you make, and what are the causes of any discrepancies?

3. Conversion Efficiency

Find the conversion efficiency ç, which is the ratio of the output signal light power to the input pump power. The theoretical maximum quantum efficiency is (why?)

$$h = \frac{l_{pump}}{l_{signal}}$$

Compare the obtained result with its simple expression.

4. Stimulated Emission Cross-Section ó$_s$

Using the following physical parameters, calculate the stimulated emission cross-section from the experimental data. State also the assumptions and the source of other physical parameters used.

The index of refraction of the core glass is n_1 = 1.46. The spontaneous transition lifetime ô = 10 ms. A reported value of the signal cross-section is ó$_s$ = 5 x 10^{-25} m^2. Compare your results with this value.

5. Population Difference N_2-N_1

Following Example 13.3 on p. 860 of *Elements of Photonics*, obtain the population difference (N_2-N_1) from the gain of the fiber amplifier.

6. Construction of a Fiber Laser

In order to construct a fiber laser, connect the output port of the EDFA to its input port by way of a star coupler as shown in Fig. 2.

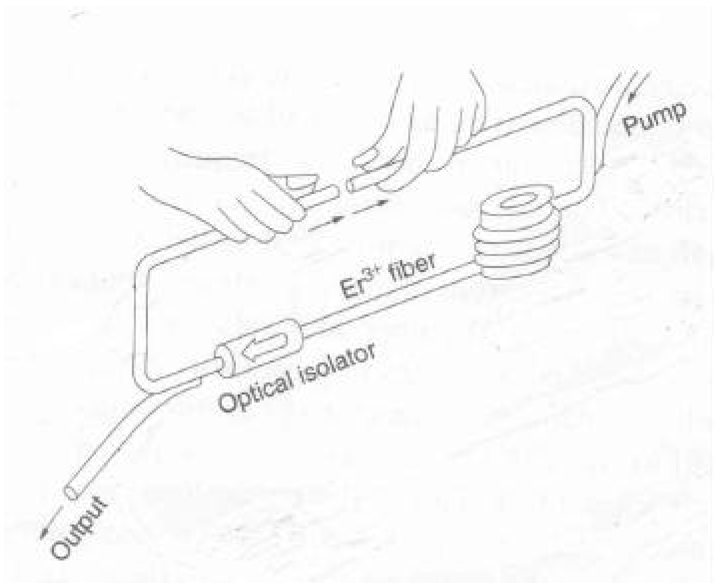


Fig. 2: Erbium-doped fiber laser

Obtain the power spectrum of the constructed fiber laser.

What are the causes of instability of the constructed laser? What kinds of counter measures do you propose to stabilize the oscillation? Discuss the properties of such a laser from practical viewpoints as a device.