ERBIUM DOPED FIBERS: CHARACTERIZATION THROUGH THE “EASY POINTS”METHOD.

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RESUMEN

En este trabajo se muestra una técnica de caracterización de fibras ópticas dopadas con Erbio por medio de la medición de parámetros de transmisión ópticos. Se describe el método de caracterización y se muestran resultados obtenidos para dos fibras de diferentes fabricantes. Con estos resultados se simula un amplificador óptico cuyas características son acordes a los reportados en la literatura.

Palabras claves: Fibras Ópticas Dopadas con Erbio, Caracterización, Amplificadores Ópticos, Parámetros de Transmisión.

ABSTRACT

In this work, a characterization technique of Erbium doped fibers through the optical transmission parameters measurement is presented. These parameters as the spectroscopic ones appropriately describe the power evolution of a light pulse that is propagating through these special fibers. Here, we present the characterization method as well as experimental results for different manufacturer fibers.

Key Words: Erbium Doped Fibers, Characterization, Optical Amplifiers.

1. Introduction

Theoretical models that are used in the design and posterior manufacturing of Erbium-doped fibers (EDF) devices are based on spectroscopic parameters such as effective sections, life times, doping ions density, etc, whose measurement is not practical. In this work, a characterization methodology of these fibers, based on the transmitted power measurements through a short segment of the fiber, is described.

The methodology consists in launching the light of a source at wavelength that one want characterize the EDF during a period of time longer than the excited-level time of the Erbium ion (~10ms)[1], so that by analyzing the output power profile in the opposite end of the fiber, it is possible to know the atomic system response.

2. Methodology Description

The Erbium ion can be treated as a two level system when is pumped with 980-nm or 1480-nm-light beams [2]. In this case, the rate equations for the Erbium ion are:

$$N = N_0 + N_1 \quad (1)$$

$$\frac{\partial N_1}{\partial t} = \frac{\Gamma\sigma_a P N_0 A}{h\nu_i} - \frac{\Gamma\sigma_e P N_1 A}{h\nu_i} - \frac{N_1}{\tau_2} \qquad (2)$$

N denotes the ion density per volume unit in the fiber with N_i (i=0, 1) ions per volume unit in i-termed level. σ_a (σ_e) represents the absorption (emission) effective sections at the wavelength of the light beam that is propagating through the fiber with transversal section A. Γ is the overlapping factor between the propagating mode field distribution and the doping ions distribution over the fiber transversal section. $h\nu_i$ is the photon energy with frequency ν_i.

The power evolution of the light beam that is propagating through the active fiber can be described using the next equation:

$$\frac{\partial P}{\partial z} = \Gamma\sigma_e P N_1 - \Gamma\sigma_a P N_0 . \qquad (3)$$

The spontaneous emission is included in the model using the term N_1/τ_2 in (2), but the amplified spontaneous emission (ASE) is looked down. Defining the normalized power of the excited state as $n_1=N_1/N$, it is possible to rewrite (3) as:

$$P(z,t) = P(0,t)e^{-\alpha z}\exp\left[\left(\frac{\sigma_e}{\sigma_a}+1\right)\alpha\int_0^z n_1(z',t')dz'\right]. \qquad (4)$$

If we define the intrinsic power saturation *Psat* and the absorption coefficient "α" as

$$\alpha = \Gamma\sigma_a N \, , \; Psat = \frac{h\nu A}{\Gamma(\sigma_e+\sigma_a)\tau} , \qquad (5)$$

it is possible to know the atomic system response by solving the coupled equations system (1-3) for a launched input signal at the fiber with a time length greater than τ_2. Due to the stationary state of the system when a long pulse is used, is easy to demonstrate that:

$$N_1(t>>\tau) = N\left(\frac{\sigma_a}{\sigma_e+\sigma_a}\right)\frac{P/Psat}{1+P/Psat} , \qquad (6)$$

$$\left.\frac{\partial P}{\partial z}\right|_{t>>\tau} = -\alpha P + \alpha\frac{P^2/Psat}{1+P/Psat} . \qquad (7)$$

By integrating the last expression, one find that:

$$\ln\left[\frac{P(z,t>>\tau)}{P(0,t>>\tau)}\right] + \frac{P(z,t>>\tau)-P(0,t>>\tau)}{Psat} = -\alpha z . \qquad (8)$$

When the input pulse is launched, it is obviously that N_1=0 for t<0, and its derivate is null for t>0, so that equation (4) is reduced to:

$$P(l,0) = P(0,0)e^{-\alpha l} .$$

(9)

This last expression indicates that the fiber absorption coefficient can be calculated if the input power $P(0,0)$ and the output power $P(l,0)$ of the optical signal are known. By replacing (8) and (9) in equation (7), *Psat* can be rewritten in terms of the "easy points" indicated in Figure 1 as [3]:

$$Psat = \frac{P2 - P1}{\eta_{out}\left[\frac{\tau}{P1}\frac{\partial P1}{\partial t} - \ln\left(\frac{P2}{P1}\right)\right]} \quad (10)$$

This means that is enough to determine the output power profile of the fiber to characterize it. The term η_{out} takes in an account the coupling factor between the fiber output and the photodetector.

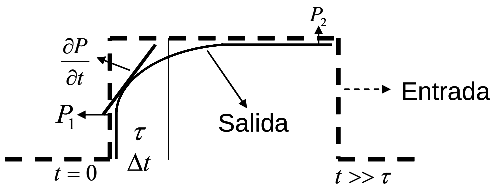

Figure No. 1. Atomic system response.

3. Experimental Setup.

A general scheme of the experimental setup used for characterizing EDF with the "easy points" methodology is presented in Figure 2. As it was mentioned, for optical amplifier and fiber lasers is convenient to characterize the fiber at λ=980 nm o λ=1480 nm (pumping) and λ=1550 nm (emission).

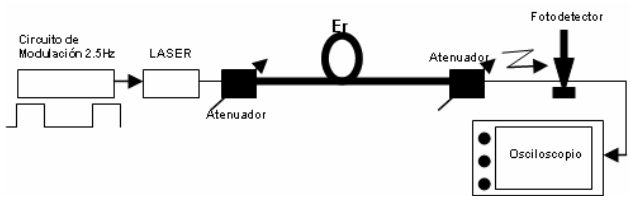

Figure No.2. Experimental setup used to characterization of EDF.

Given the method's conditions, the light source at the appropriated wavelength was modulated with a signal generator at 2.5 Hz, in this way was guarantee the necessary conditions by the method described in section 2.

4. Results

A typical experimental output-power profile is shown in Figure 3. We characterize two fibers which results are shown in Table 1.
With the obtained experimental results, it was simulated an optical amplifier for both fibers [4], see Figure 4. As it was expected, the Liekki product brings a greater gain for a doped fiber with the same length and pumping power due to the largest concentration of Erbium ions.

Table No 1. Experimental acquired fibers transmission parameters.

Manufacturer	*Psat(1550nm)*	*α (1550nm)*	*Psat(980nm)*	*α (980nm)*
CPqD-Telebrás (Brazil)	279.3μW	$0.52m^{-1}$	148.6μW	$0.952m^{-1}$
Liekki (Finlandia)	324.1μW	$2.15m^{-1}$	262.9μW	$2.79m^{-1}$

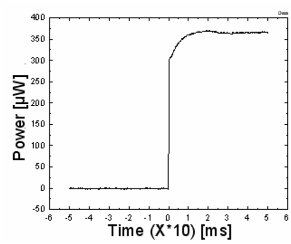

Figura No.3. Typical experimental curve of characterization.

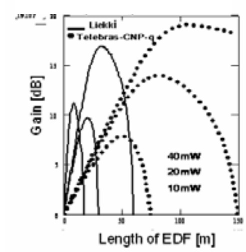

Figure No.4. Optical Amplifier Simulations

Conclusions

In this work is presented a simple method to characterize Erbium Doped Fibers based on transmission parameters. With the experimentally acquired results it was simulated an optical amplifier with similar results to others previously reported.

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