This poster is created for:

IEEE Swedish Communication Technologies Workshop
19-21 October 2011, Stockholm

ESTIMATION OF ERBIUM DOPED OPTICAL FIBERS EFFECTIVE AREA

Andis Supe *IEEE Graduate Student Member,* ***Jurgis Porins*** *Dr.sc.ing*
e-mail: andis.supe@rtu.lv; jurgis.porins@rtu.lv;

Riga Technical University, Institute of Telecommunications
Address: Azenes str. 12, LV-1048, Riga, Latvia

IEEE

ABSTRACT

Erbium doped fiber amplifier is one of the most often used amplifier in the fiber optics transmission systems as its amplification window coincides with the third transparency window of silica-based optical fiber. In this research effetive area of erbium-doped optical fibers were studied experimentally by transverse shift measurement method for the excitation at 980 and 1480 nm wavelengths and at the amplification range of 1520 - 1630 nm. Based on the experimental results, the fiber effective area and the optical radiation intensity in the erbium doped optical fiber have been calculated.

1. Introduction

The erbium-doped optical fiber amplifier (EDFA) design is based on fibers with a small controlled amount of erbium (a rare-earth element) added to SiO_2 in the form of Er^{3+} ion. EDFA amplification range is around 1550nm wavelength. These type of amplifiers are distinguished by comparatively less noise; they are sensitive but slightly to the signal polarization, have minor connection losses, and do not introduce inter-channel distortions.

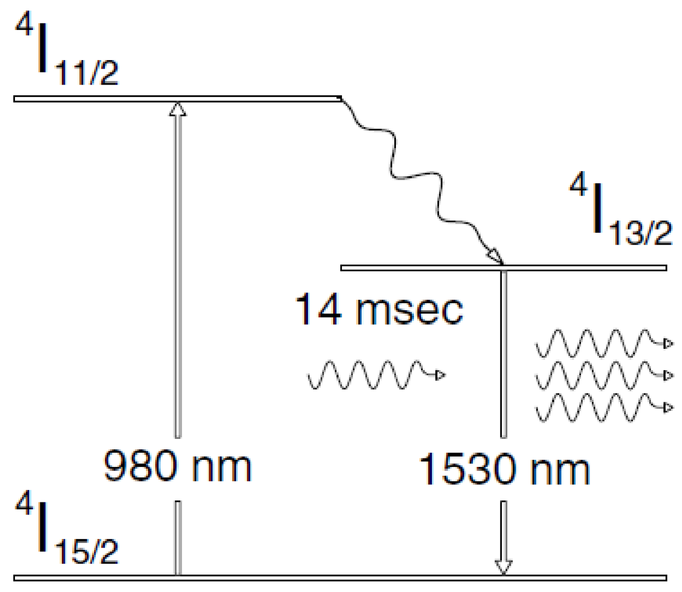

Fig.1. Three level system of EDFA [1]

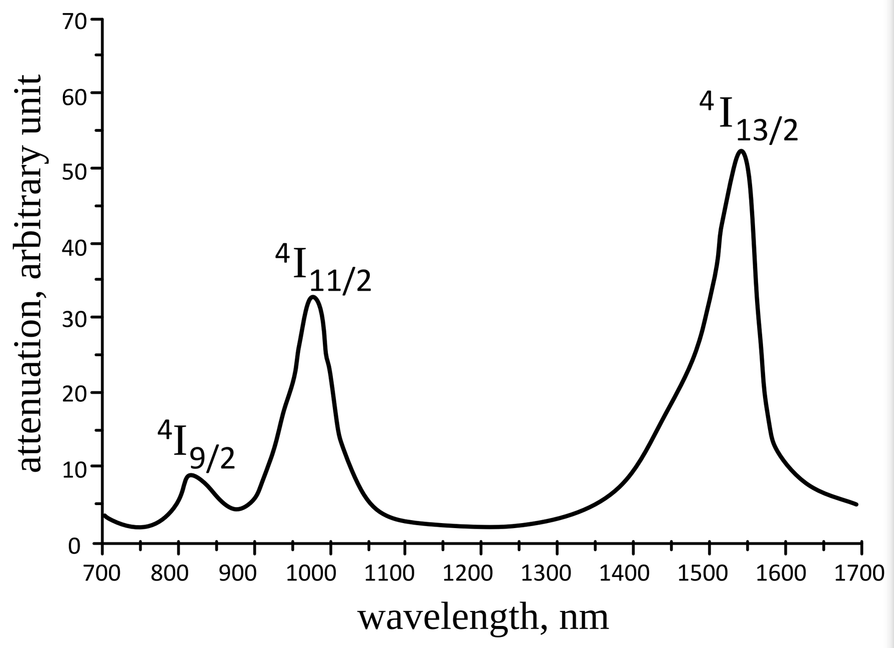

Fig.2. Absorption spectrum of an erbium doped silica fiber [2]

2. Fiber effective area

All nonlinear effects depend on the electro-magnetic field intensity in the relevant environment. The optical power measured at fiber's output is merely an integral from the intensity distribution over the entire area of a fiber's cross-section. The intensity in a core with the area A_c can be calculated from the measured power P_m:

$$I = \frac{P_m}{A_c}$$

The effective area of optical fiber can be defined as:

$$A_{eff} = \frac{2\pi\left(\int_0^\infty |E_a(r)|^2 r dr\right)^2}{\int_0^\infty |E_a(r)|^4 r dr} = \frac{2\pi\left(\int_0^\infty I(r) r dr\right)^2}{\int_0^\infty I^2(r) r dr}$$

In this research we used transverse shift A_{eff} measurement method. In such a way we can achieve far field distribution from the power transferred from one fiber to the other. Near field distribution can be calculated through the far field power distribution using Henkel transformation. Further effective area can be obtained using the near-field power distribution.

3. Measurement scheme

Realized experimental transverse shift measurement scheme:
1) High power tunable laser sources Agilent 81949A and 81989A
2) Micro-positioner Standa 8SMC1-USBh
3) Wavelength and power meter EXFO WA-1150.

Micro-positioner allows to shift fiber end in three different space dimensions. Full step size for micro-positioner is 1.25μm with possibility to reduce it up to 1/8th.

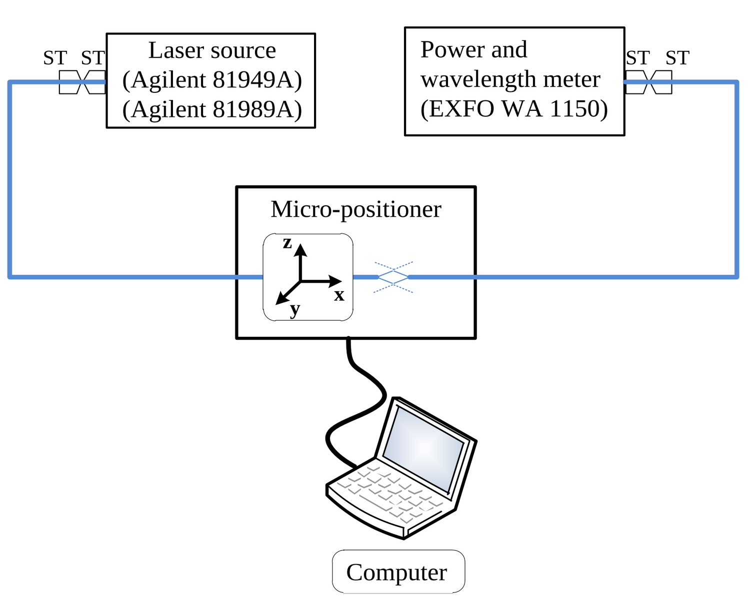

Fig.3. The block diagram of the experimental measurement scheme

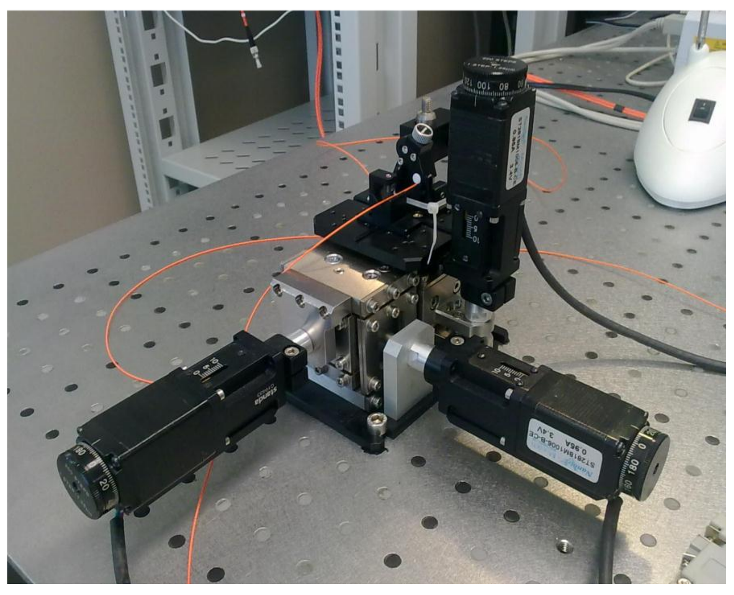

Fig.4. Micro-positioner Standa 8SMC1-USBh

4. Results

Based on the measured power distribution results and the model for their processing described previously the erbium doped fiber's (EDF) effective area values and the optical radiation intensity have been calculated.

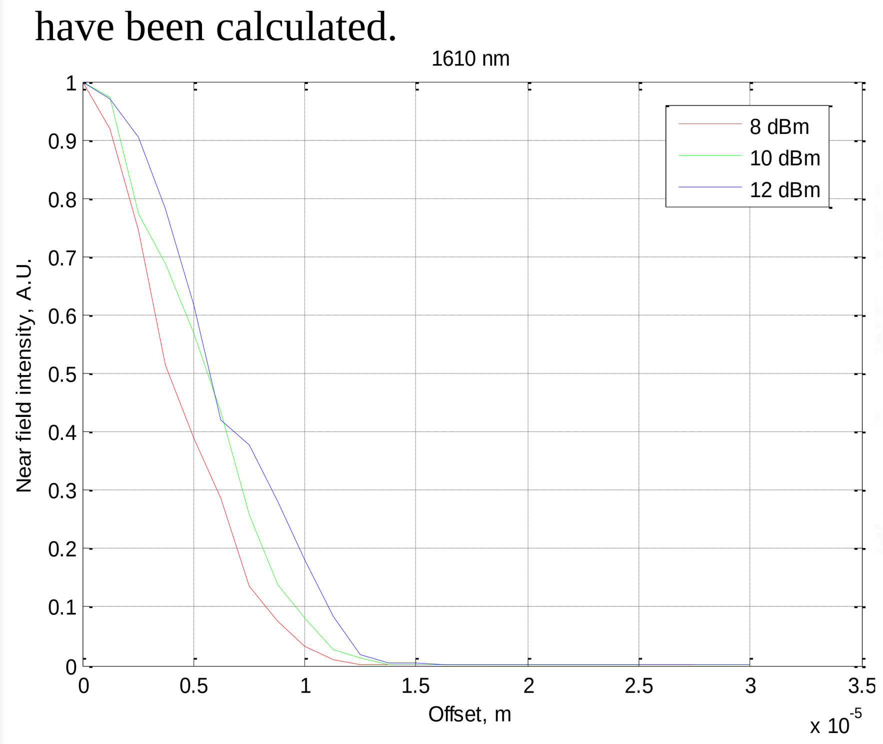

Fig.5. The measured optical radiation distribution vs the fiber transverse shifting at 1610 nm and three input optical power levels 8, 10 and 12 dBm.

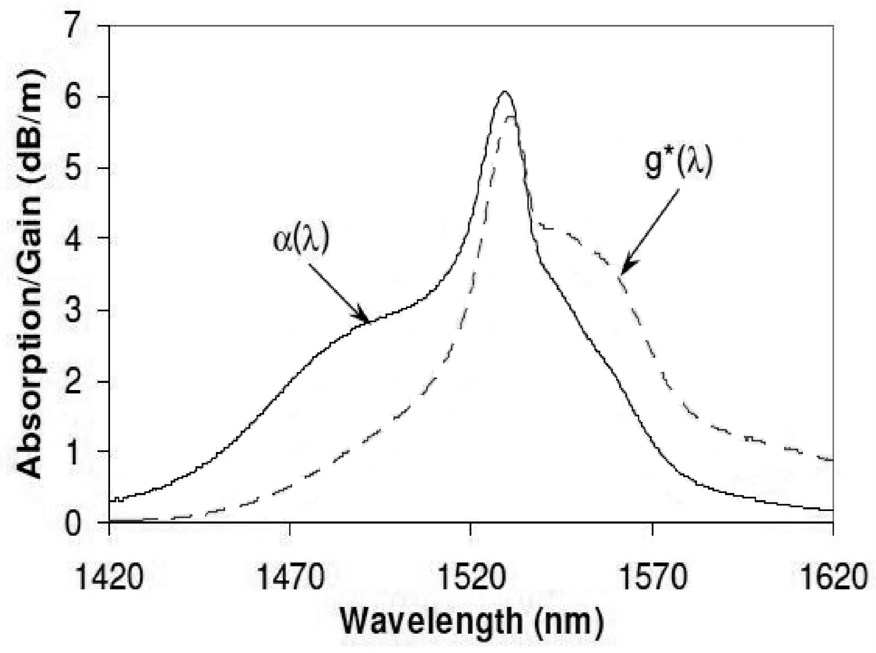

Fig.6. Absorption and gain parameters for the Er-doped fiber. [2]

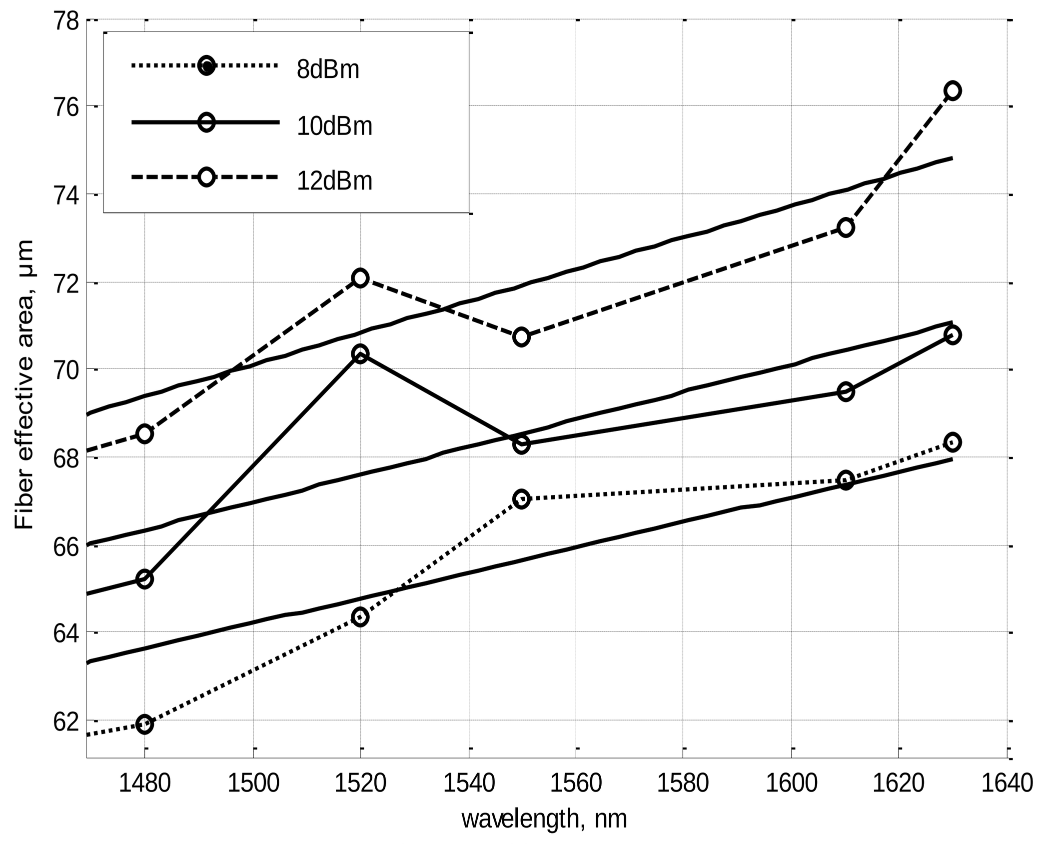

Fig.7. Erbium doped fiber effective area *vs* wavelength (nm) at three different optical power levels.

The values of the fiber effective area are in the range from 49.50μm^2 at λ=980nm and P_{in}=8dBm to 76.34μm^2 at λ=1630nm and P_{in}=12dBm. Measured effective area at λ=980nm is considerably smaller than for other wavelength. The explanation for this is that there are one of absorption maximums at λ=980nm (*Fig.2*). From measurement results (*Fig.7.*) we can notice a local A_{eff} maximum around 1520nm. It could be related with EDF fiber gain characteristics (*Fig.6.*).

Optical intensity calculations

Although EDFA amplifier working principle is not directly associated with nonlinear optical effects it depends on optical signal intensity in EDF. Besides nonlinear effects can occur in EDF simultaneously with amplification due to optical fiber nonlinear characteristics. So it is significant to evaluate refractive index change of these fiber due to third order nonlinearity or so called Kerr effect.

The values of the optical intensity are in the range from 92.35MW/m² at λ=1630nm and P_{in}=8dBm to 308.23MW/m² at λ=980nm and P_{in}=12dBm. These results are inversely proportional to A_{eff} results. From intensity change we can evaluate refractive index nonlinear part n_2 change. This change in the EDFA amplification region at different optical power levels and wavelength is found to be 2.43 times.

Our further research include more detailed EDF A_{eff} measurements around λ=1530nm and EDF nonlinear coefficient determination using picosecond optical pulses.

		Optical intensity, MW/m²		
	Input power	8 dBm	10 dBm	12 dBm
λ, nm	980	127,47	198,18	308,23
	1480	101,92	153,35	231,34
	1520	98,08	142,17	219,91
	1550	94,13	146,46	224,11
	1580	93,82	145,20	220,30
	1610	93,50	143,93	216,49
	1630	92,35	141,30	207,61

The optical intensity in EDF for different wavelength and power values of the optical signal

REFERENCES

[1] Prof. Dr.-Ing. Dickmann, ''Erbium Doped Fibre Amplifier'', 2003, -10p.

[2] P. C. Becker, N. A. Olsson, J. R. Simpson, Erbium-Doped Fiber Amplifiers, - Academic Press, 1999. -481p.

ACKNOWLEDGMENT

This work has been supported by the European Regional Development Fund in Latvia within the project Nr. 2010/0270/2DP/2.1.1.1.0/10/APIA/VIAA/002 and by the European Social Fund within the project „Support for the implementation of doctoral studies at the Riga Technical University".

RIGA TECHNICAL UNIVERSITY

ERAF EIROPAS REĢIONĀLĀS ATTĪSTĪBAS FONDS

ESF EIROPAS SOCIĀLAIS FONDS

INSTITUTE OF TELECOMMUNICATIONS