Semester S1 – Fundamentals of coherent optics

Fiber amplifiers, tutorial #1

We consider a cylindrically symmetric singlemode fiber doped with Er^{3+} ions in the core. The Er-doping with concentration $N_0 = 2\times10^{24}$ m^{-3} is uniform across the doped region of radius a_d. The fiber is forward-pumped at 980 nm and seeded at 1550 nm (signal).

1. The fiber is described by its numerical aperture NA = 0.21 and core radius a = 1.5 µm.

Show that the EDF is singlemode whatever the operating wavelength (signal and pump).

2. We consider the Gaussian approximation for the field distribution $\psi(r,\theta)$

$$\psi(r,\theta) = \frac{1}{w}\sqrt{\frac{2}{\pi}}e^{-\frac{r^2}{w^2}}$$

where w is the mode field radius of the guided mode and where the multiplying factor $\frac{1}{w}\sqrt{\frac{2}{\pi}}$ is chosen to normalize $\psi(r,\theta)$ so that $1 = \int_0^{2\pi}\int_0^{\infty}\psi^2(r,\theta)rdrd\theta$, where $\psi^2(r,\theta)$ corresponds to the field intensity.

Recalling that $\left(e^{ax^2}\right)' = 2axe^{ax^2}$, show that for a uniformly doped region of radius a_d, the overlap factor between the light intensity distribution and the doped region is given by

$$\Gamma = 1 - e^{-2a_d^2/w^2}$$

The mode field radius of the guided mode was calculated by solving the Helmholtz equation for the step-index fiber and plotted in Fig. 1:

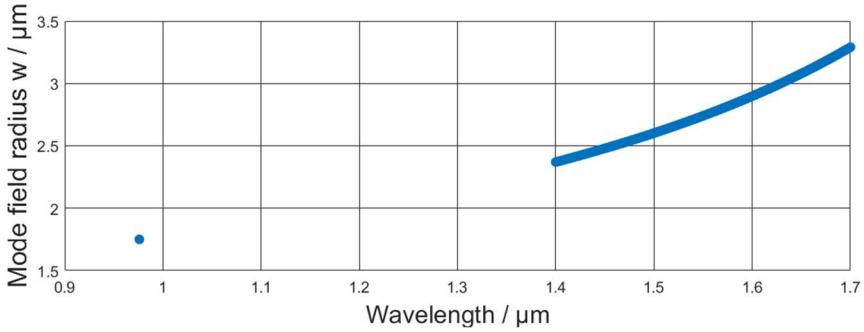

Fig.1: Mode field radius w versus wavelength

Calculate Γ at the two wavelengths of 976 nm and 1550 nm for $a_d = a$.