Doubts and results

1. Recovery of a distribution of intensity inside a homogeneous fiber from the transfer function. The experimental data are simulated. Transfer function is extended to the complex domain. The approximation of the equation with 6 decimal digits is possible (while I know the solution), but the convergence of the iterational algorithm depends on the reference plane. Play with real experimental data is necessary to understand whether the algorithm is robust or not.

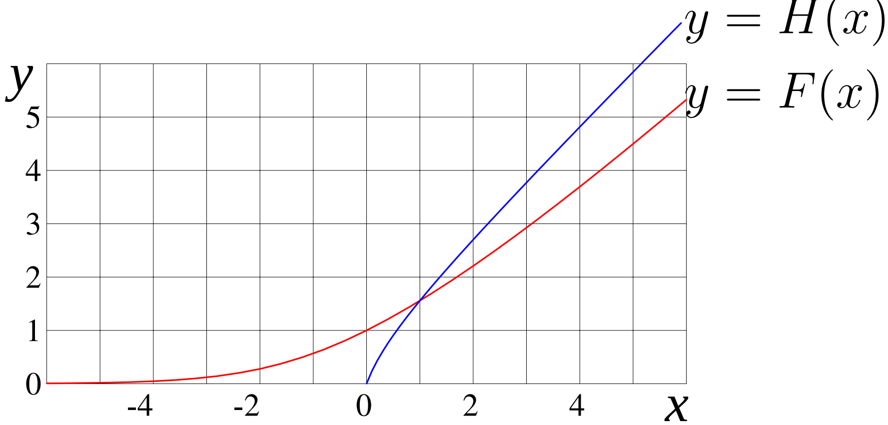
2. Parameters of bounded mode in the experiment by Michel is estimated; size of this mode is much than radius of the core. Two hypothesis are formulated:
2A. The confined mode becomes leaky due to the bending of the fiber.
2B. The confined mode gets mixed with other modes due to the internal defects of the fiber.

3. Diagonalizer for for paraxial propagation of waves in waveguides is installed at computers of Michel (Macintosh) and Doya (Linux). For testing, we removed the core and approximated modes of D-shaped fiber with Dirichlet boundary condition. At least first 100 modes agree with picture in the blue folder from Doya's office (plane waves decomposition), but the transversal wavenumbers are 1% lower. The difference does not vanish when we drop the grid. I doubt in the convergence of the plane waves decomposition method. It should fail for singular functions, for ex., $\Psi = J_\nu(\rho)\sin(\nu\varphi)$ at non-integer ν.

4. Launching conditions for propagation of low modes in the $LiNbO_3$ fiber are not found. Hypothesis that the ends of the fiber are spherical surfaces is analyzed. The radius of curvature is estimated to be (16 ± 1) mm

5. Self-consistence of specifications for another $LiNbO_3$ sample is analyzed. The interferometric refractometer is mounted in laboratory. Value of the refraction index $n = 2.34$ is measured (for both polarizations), that should be compared to specifications $n_{\rm o} = 2.2028$, $n_{\rm e} = 2.2866$.

1. Reconstruction of distribution from the transfer function Assume, there is some analytic monotonous (at the real axis) function $F(z)$ and it is known that if $F(z) = f$, then $F(z+1) = H(F(z))$.
Assume $F(0) = 1$. How to recover F from the transfer function H? Use of the Cauchi integral was suggested; it leads to the integral equation for values of F at the imaginary axis. For $G = \exp$ and for $G = \exp_2$, the straightforward iteration converges within 64 iterations.
Approximation and convergence of the same algorithm for more realistic transfer functions is analyzed. Case $F'(z) = F(z)/(1+F(z))$ is considered as an a model for the uniformly-pumped saturated fiber amplifier. The solution can be written as $F(z) = V^{-1}(z)$, where $V(f) = f + \ln(f) + 1$.
Functions V, F and the transfer function $H(f) = F(1+V(f))$ are implemented.

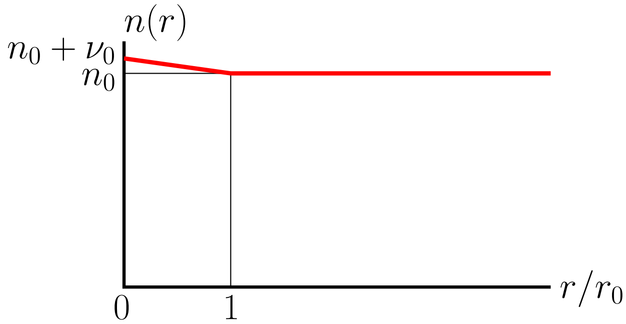


Convergence depends on the contour of integration; should check it for the real data.

2. Mode of Claire Michel

The mode for the triangular distribution of index of refraction is considered:

$\Phi'' + \frac{1}{r}\Phi' + (n(r)^2 k_0^2 - \beta^2)\Phi = 0$ $\Phi(r) = r(r/r_0)$



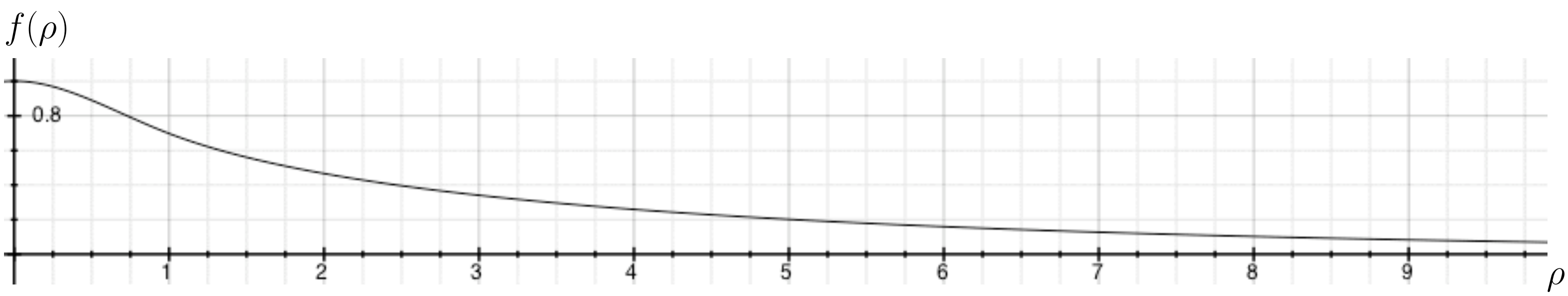
$$\mu(x) = \begin{cases} 1-x & , \ x \le 1 \\ 0 & , \ x \ge 1 \end{cases}$$

$$f''(x) + \frac{1}{x} f(x) + (-q + p\mu(x)) f(x) = 0$$

$q = (n_0^2 k_0^2 - \beta^2) r_0^2$, $p = 2\nu_0 n_0 k_0^2 r_0^2$

$n_0 = 1.451$, $\lambda_s = 1020$nm, $\nu_0 = 4 \times 10^{-4}$, $2r_0 = 15\,$micron

I calculate $p \approx 2.4$; then $q \approx 0.0256$; $\sqrt{q} \approx 0.16$.



Why this mode is not seen in experiments?

A. Poor overlap with core, low gain?

B. Leak at the bending?

C. Fluctuations of index of refraction?

Suggestions:

Calculate the modes.

Compare the overlap with that of scar modes.

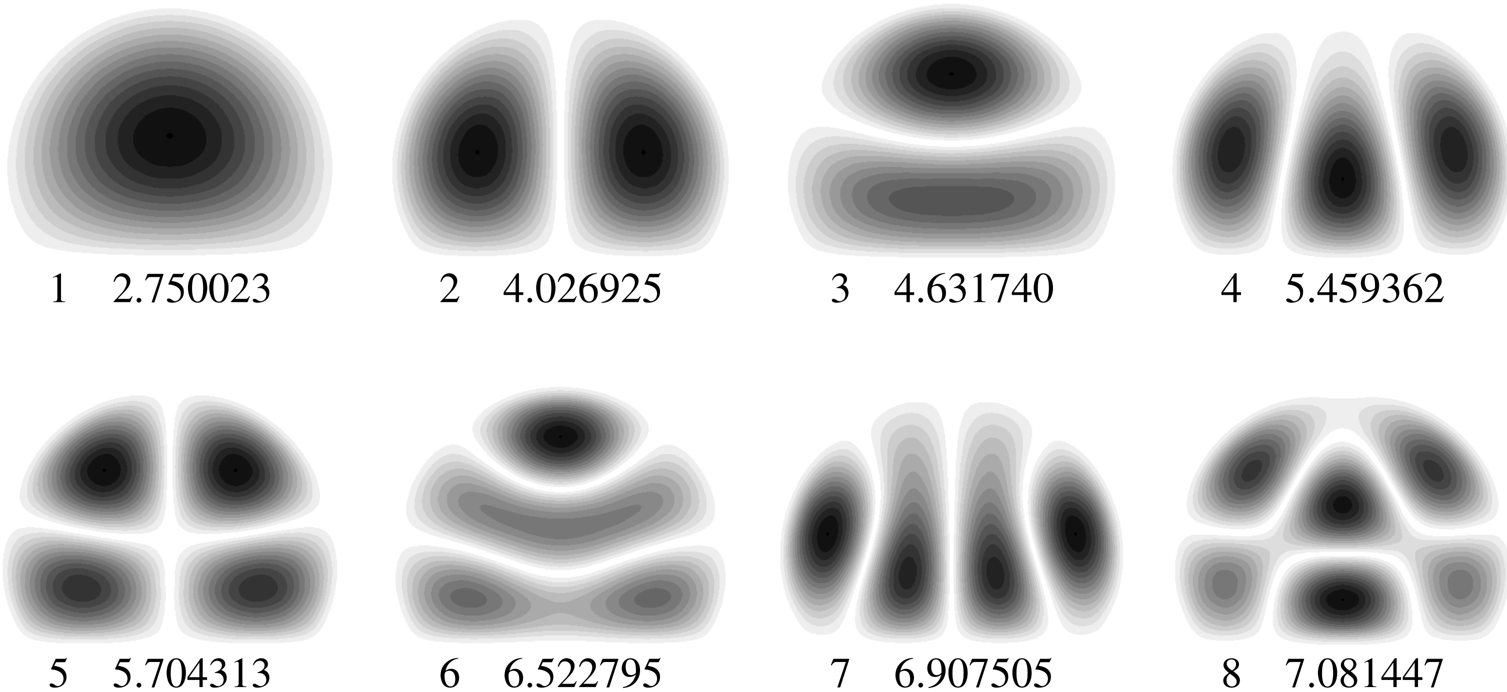
Launch the principal mode into a short piece of straight fiber.

C.Michel, V.Doya, O.Legrand, F.Mortessagne. Selective Amplification of Scars in a Chaotic Optical Fiber. PRL 99, 224101 (2007)

3. Calculations of modes

D.Kouznetosv, J.Moloney. Efficiency of pump absorption in double-clad fibers amplifiers.3. Calculation of modes. JOSAB **19** 1304-1309 (2002)

The diagonalizer is installed at two computers and tested. We removed the core and run it for D-shaped fiber. At least first 100 modes coincide with those obtained by the plane wave decomposition.

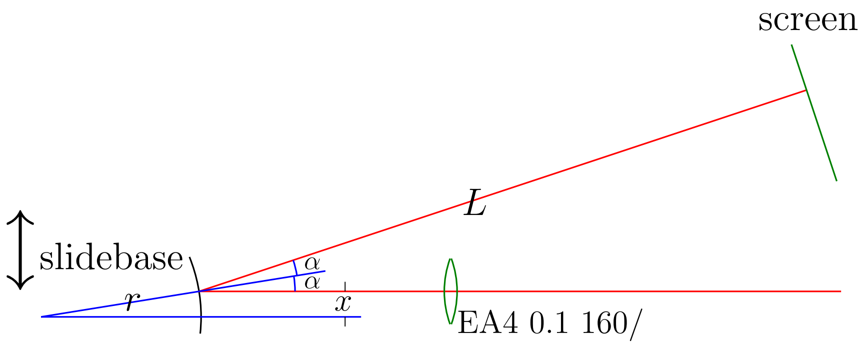


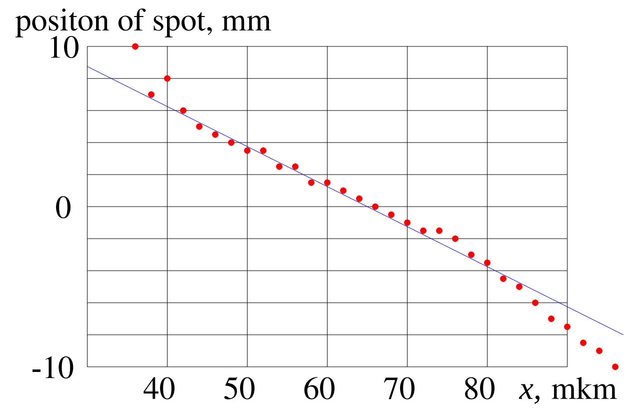
Proposals for the future work:
Compare the residuals: whose eigenvalues are correct?
Check the BPM method for short fiber: how well do overlap the measured and simulated profiles of the transversal distribution of power?
Substitute the beam propagation method to the mode decomposition compare the results.

Propagation of light through the samples polished by Sorin: "fiber"

For the nonlinear condensation of modes, the $LiNbO_3$ is suggested to emulate cubic nonlinearity. The fiber-shaped sample of diameter 0.5mm of the wavelength 1cm and the slab 0.5mm x 2mm x 20mm were analyzed.
No trough propagation of plane waves through the fiber was achieved; the input plane wave from He-Ne laser was completely destroyed after the propagation through the sample; the chaotic wave at the output should be attributed to linear inhomogeneity of the sample.
In the backscattering test, the perfect ring was observed. This ring can be caused by reflection from the surface of the sample surrounding the fiber. The dark spot at the center could be due to curvature of the surface of the core. In order to check this hypothesis, the simple reflectometer is mounted.

Measurement of radius of curvature





Distance to the screen $L = 20\,\mathrm{cm}$ (measured with ruler)

displacement of fiber x (measured with slidebase)

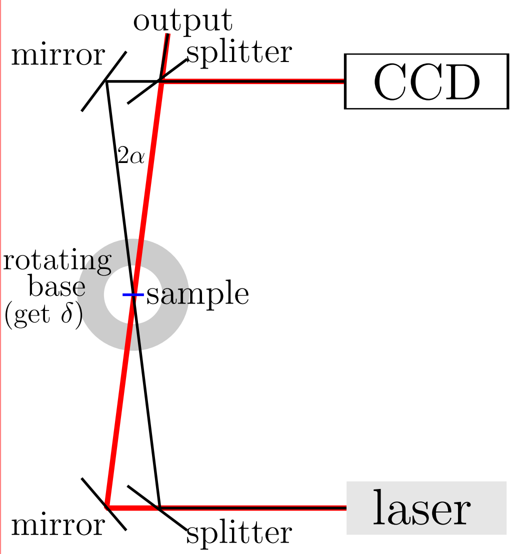
displacement of the spot at the screen $y = 2\alpha L = \frac{2L}{r}x$ (measured with millimetric paper)

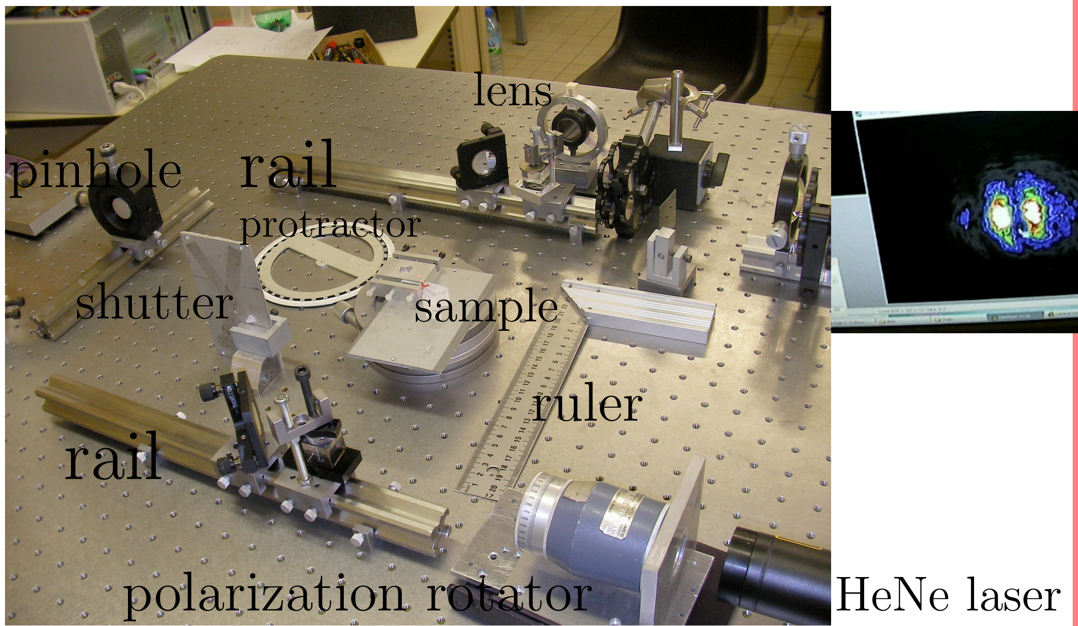
Fit: $\frac{2L}{r} = 0.25\frac{\mathrm{mm}}{\mathrm{micron}} = 250$ (from the graphic)

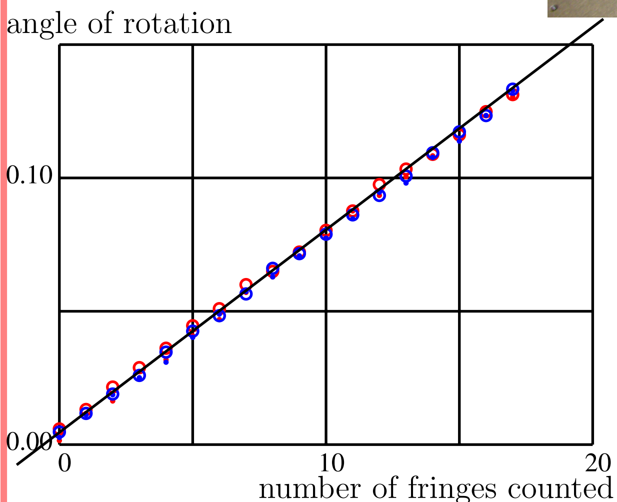
Estimate: $r = 2L/250 = 16\,\mathrm{mm}$

For propagation of a plane wave, the input should be focused in to a spot of size of $\sim$ 20micron at the distance of order of 13 mm from the ends of the fiber. This can be done with lenses of focal distance of order of few cm.

Propagation of light through the samples polished by Sorin: slab, index of refraction







$s = \sin(\alpha)$, $c = \cos(\alpha)$; $h = 500\,\mu$ is thickness ; $\lambda = 0.6328\,\mu$;
2α is angle between beams that cross at the sample.
$\delta \approx 0.076$ is angle of rotation shifting pattern for one strip.

$$n = s^2 + \frac{c^2}{\left(1 - \frac{\lambda}{2hs\delta}\right)^2} \approx 2.34 \qquad \text{(for both polarizations)}$$

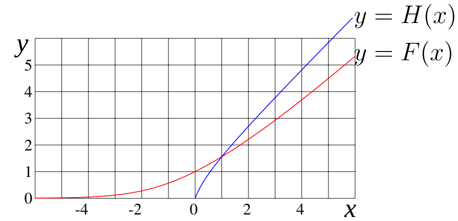
instead of

$$n_{\mathrm{o}} = 2.2028$$
$$n_{\mathrm{e}} = 2.2866$$

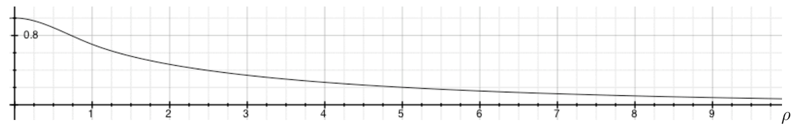
(measured again the an

Proposals

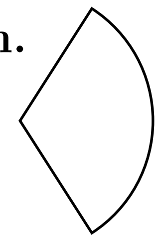
1. Reconstruct the distribution of (power) $F(z)$ from the transfer function $H(f) = F(t + F^{-1}(f))$



2. Compare the overlapping with core of the scar mode to that of the principal mode.

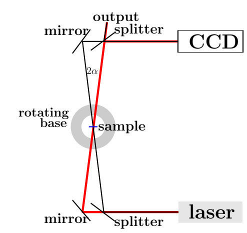


3. Check the method of the plane wave decomposition. Does it work for a sector? Plot the approximation of mode Ψ and Ψ'' along the boundary of the domain.



4. Check sphericity of tips of the $\mathrm{LiNbO_4}$ fiber. Achieve the propagation of a plane wave inside.

5. Test my interferometer. Can it measure also the nonlinear phase shift?



6. Return to the nonlinear condensation of guided modes.