Status of 100 W Rod System at LZH

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Outline

Modeling

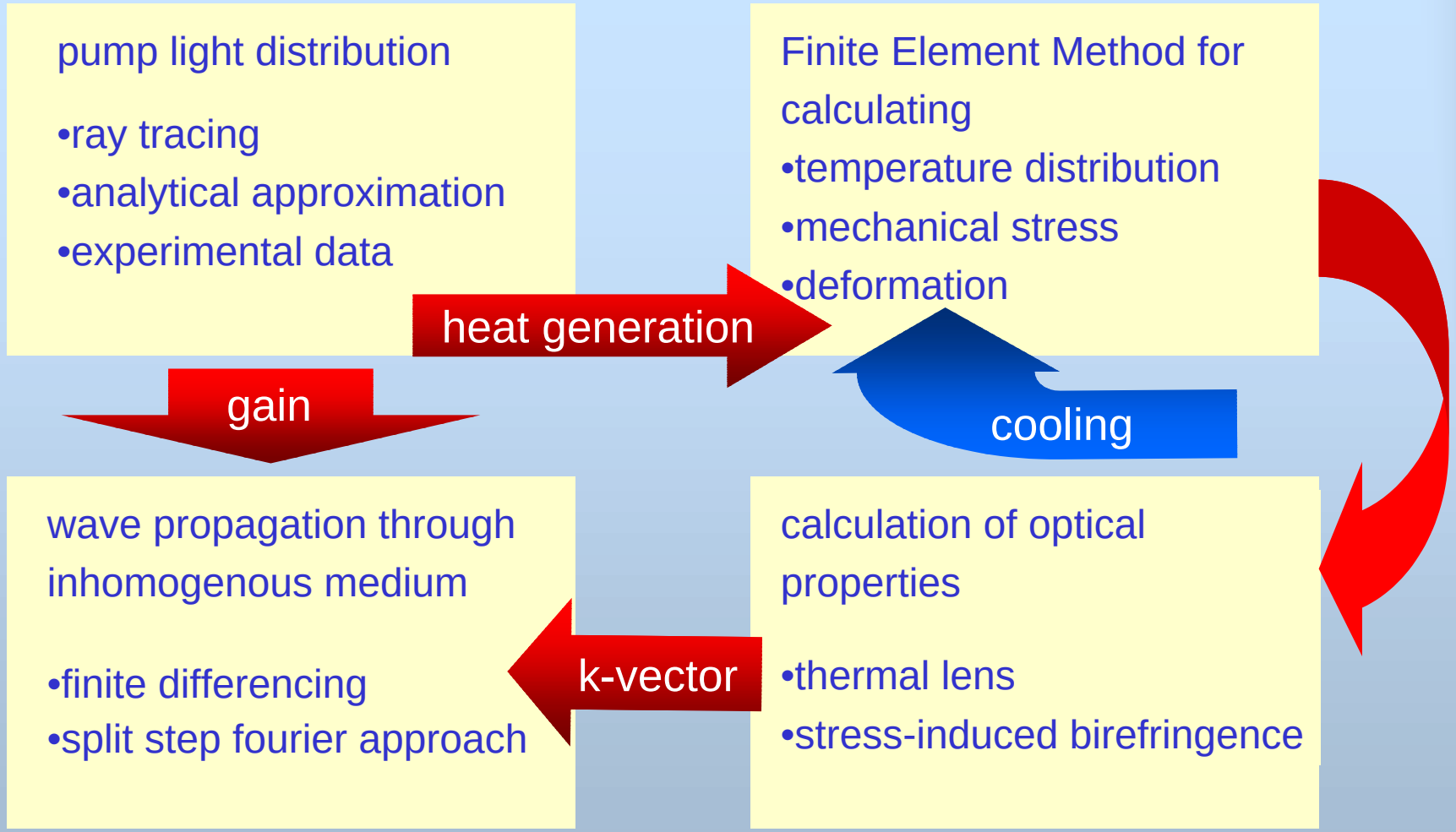
- Overview
- Results

Experimental results

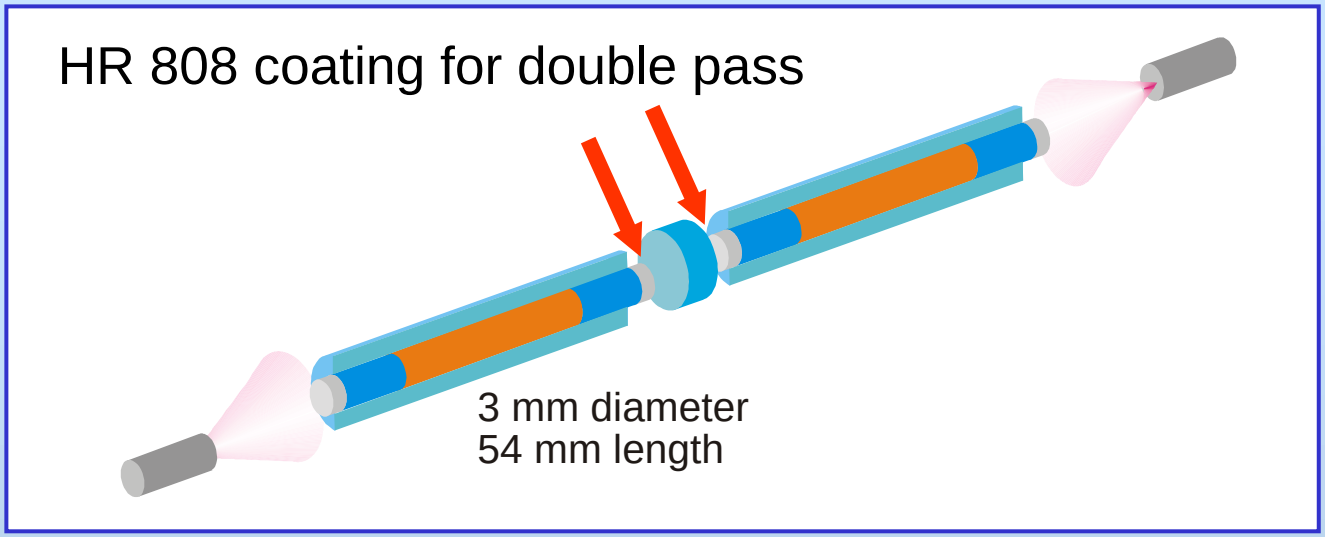
- Integrated Diode Units
- Pump Optics
- Pre-Experiments

Resumé/Outlook

Modeling/Overview



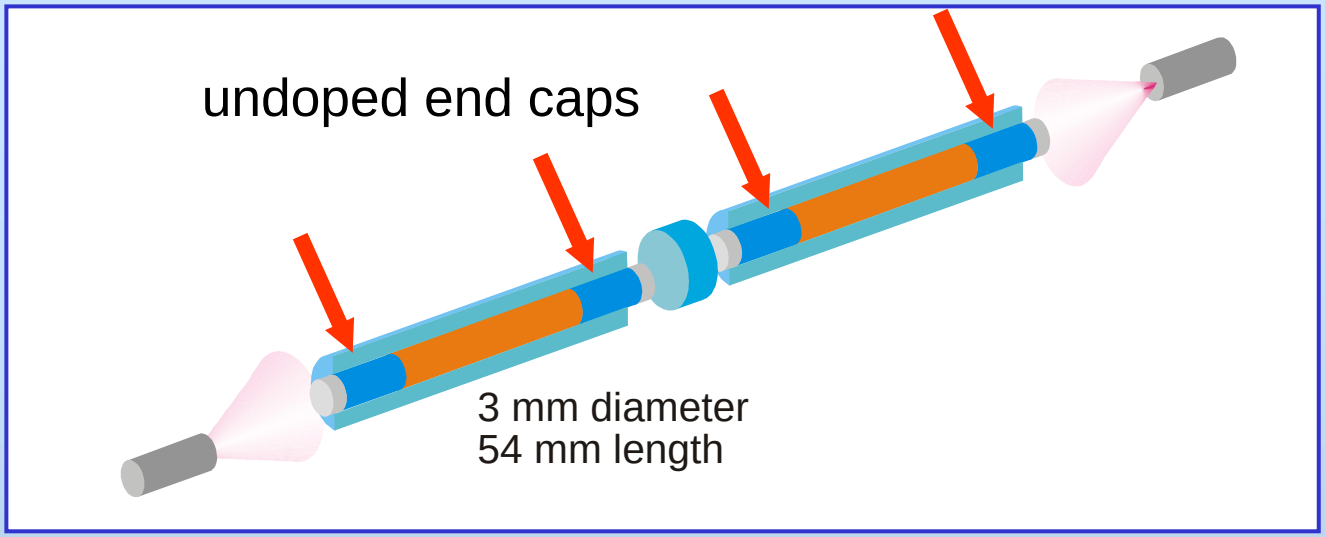
100 W Laser Head



- end-pumped rods

  reduce thermal gradient in z-direction

100 W Laser Head



•end-pumped rods

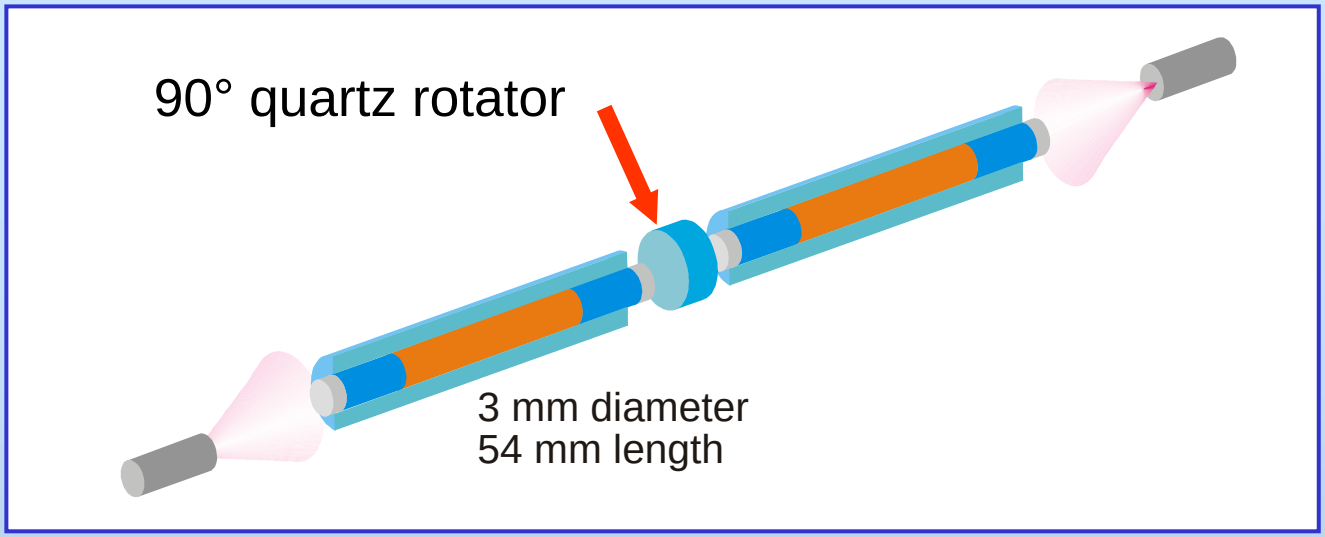
thermal lensing consists of two parts

thermal part via dn/dT

end effect (bulging of end surface)

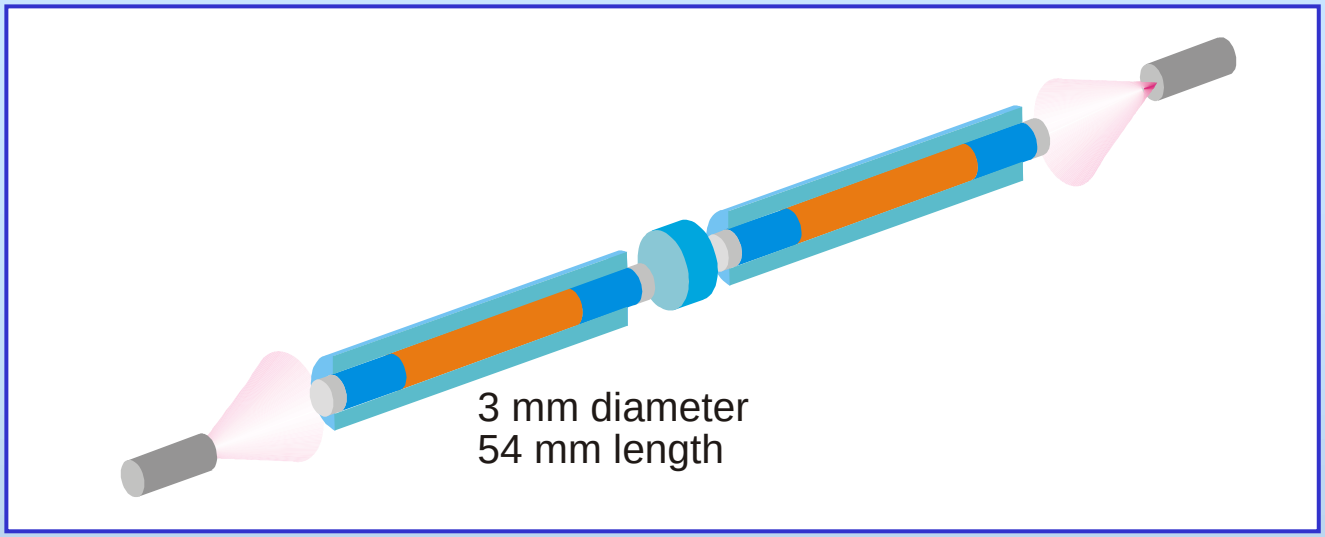
reduced by undoped endcaps

100 W Laser Head



- end-pumped rods
- undoped endcaps reduce absolute temperature and thermal lens
- 90° quartz rotator compensates for birefringence

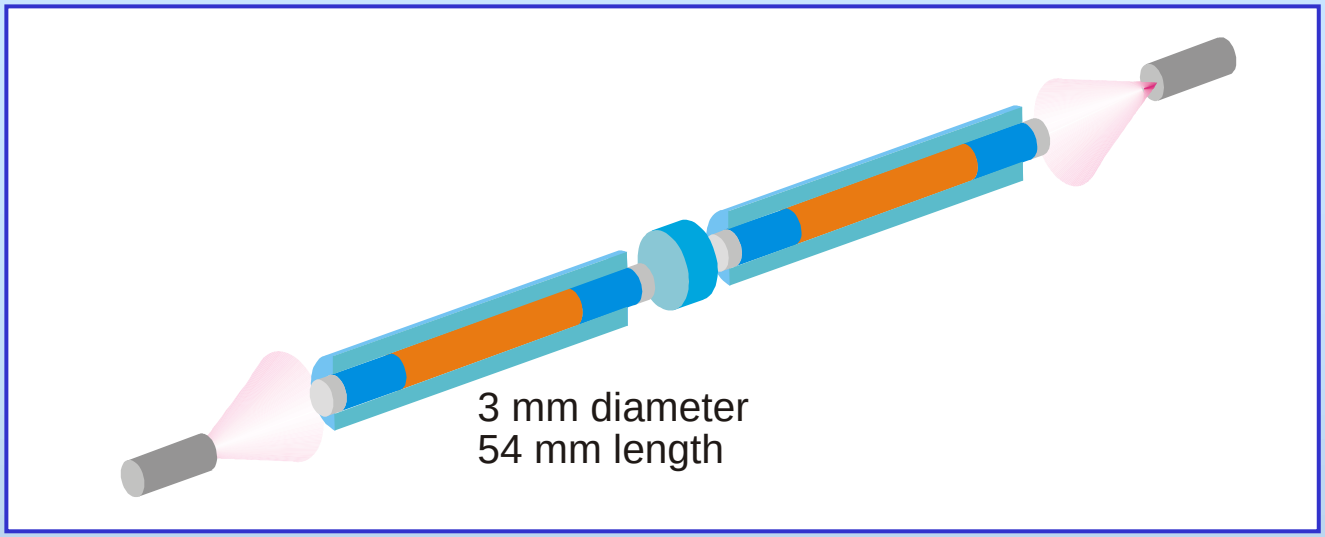
Model



assumption:

cylinder symmetrical pump light distribution

Model



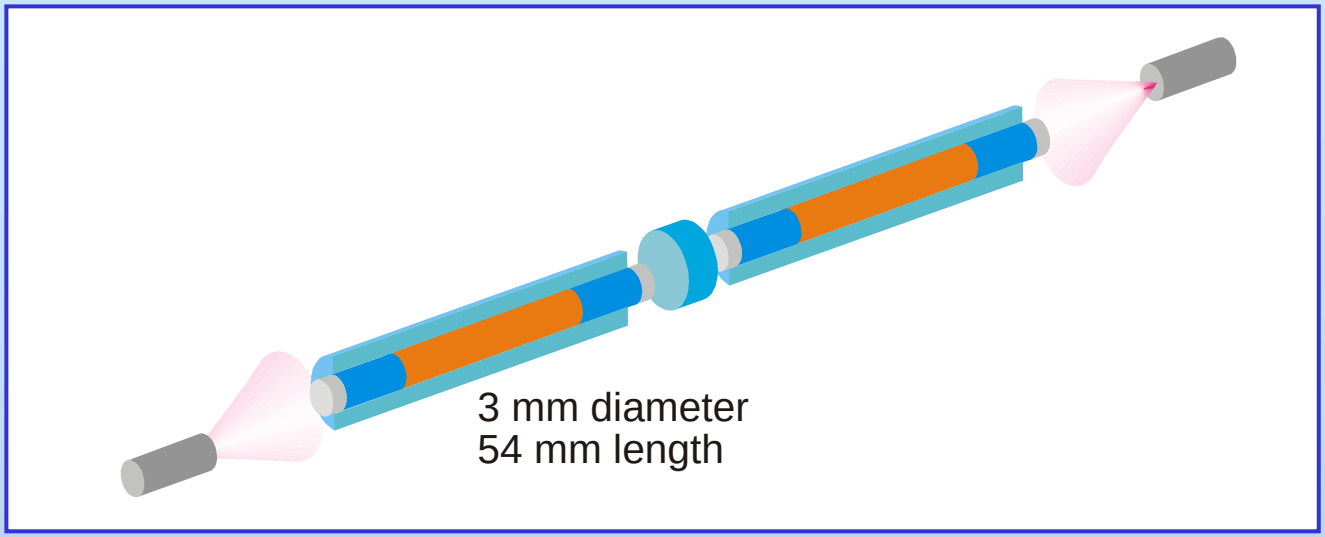
assumption:

cylinder symmetrical pump light distribution

•model takes into account wavelength/temperature dependent properties

wavelength dependent absorption coefficient

Model



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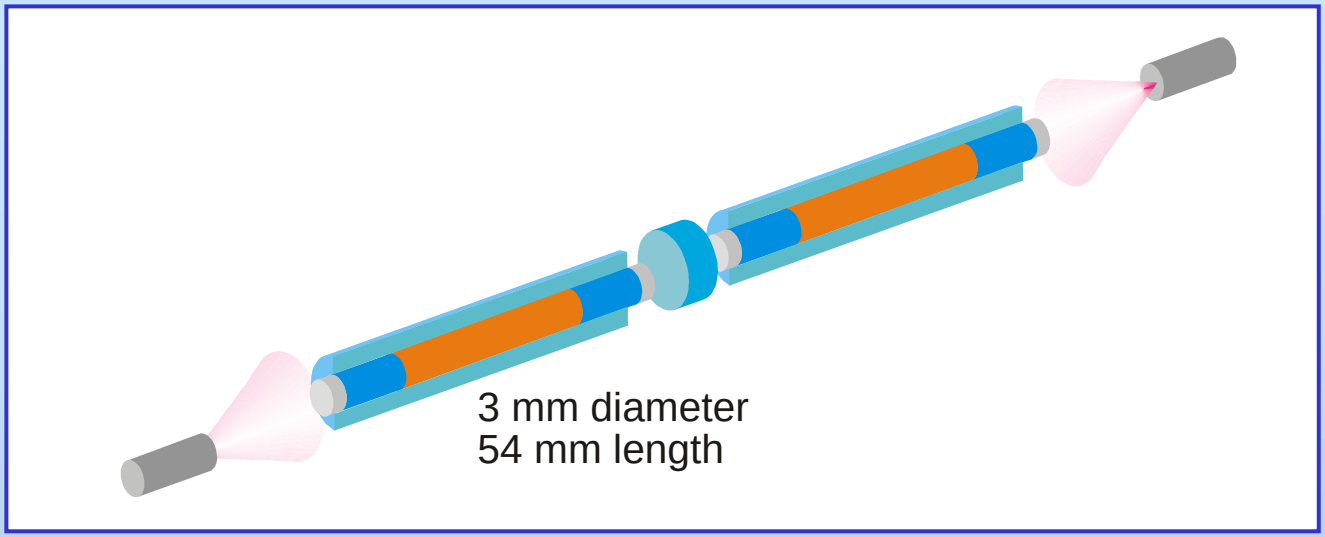

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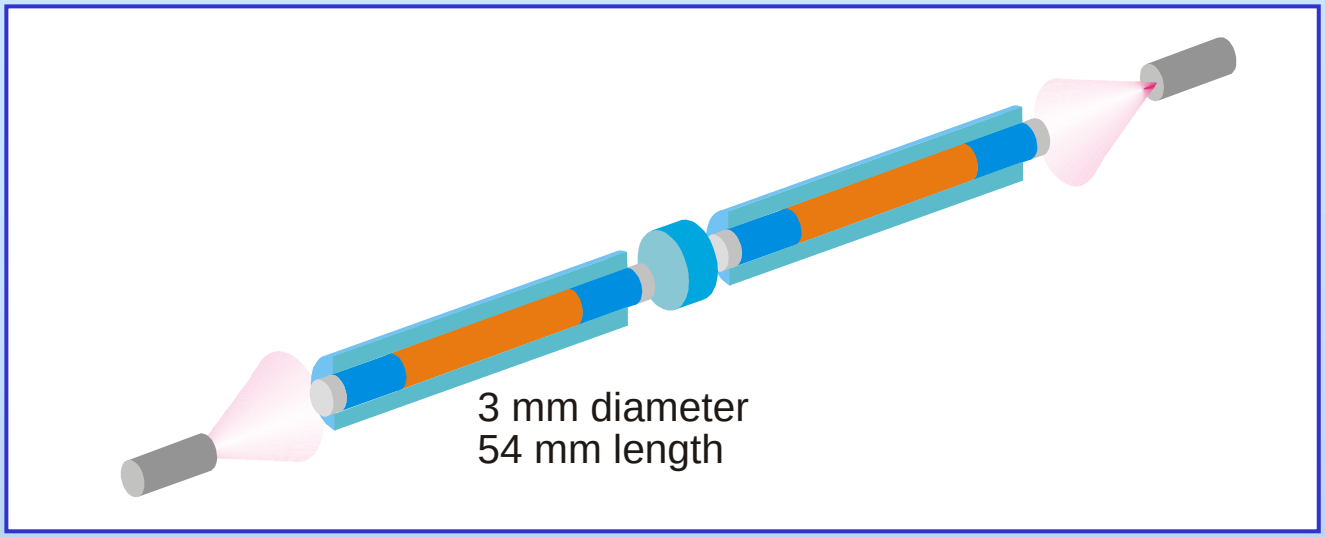
- model takes into account wavelength/temperature dependent properties

wavelength dependent absorption coefficient

temperature dependent heat conductivity

temperature dependent expansion coefficient

Model



assumption:

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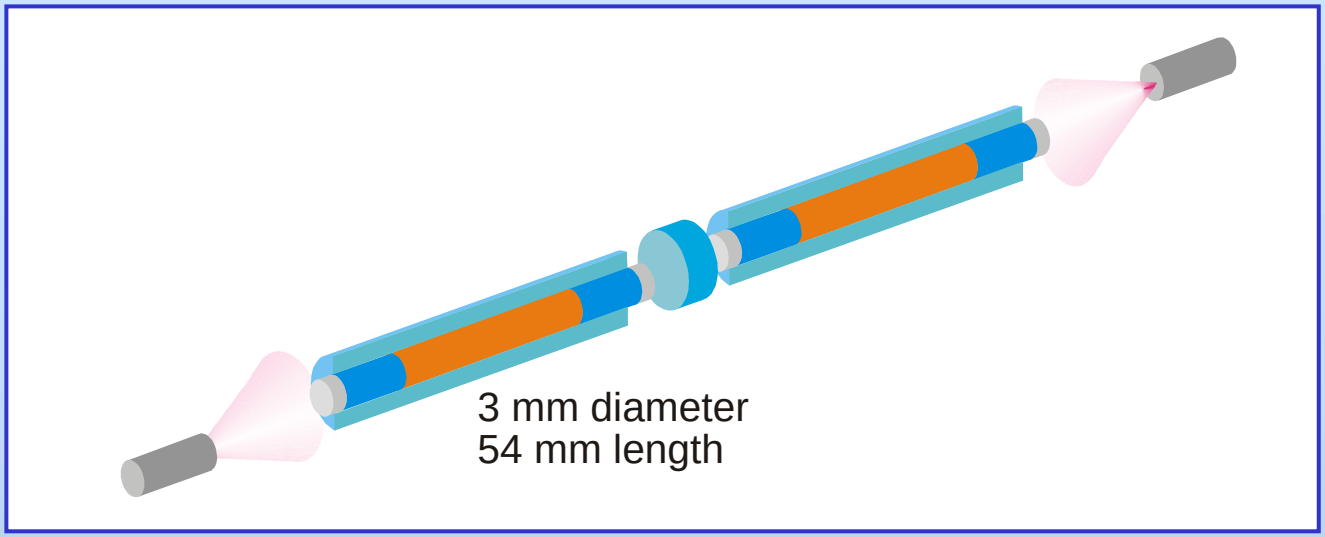
wavelength dependent absorption coefficient

temperature dependent heat conducitvity

temperature dependent dn/dT

temperature dependent expansion coefficient

Model



assumption:

cylinder symmetrical pump light distribution

- model takes into account wavelength/temperature dependent properties

  wavelength dependent absorption coefficient

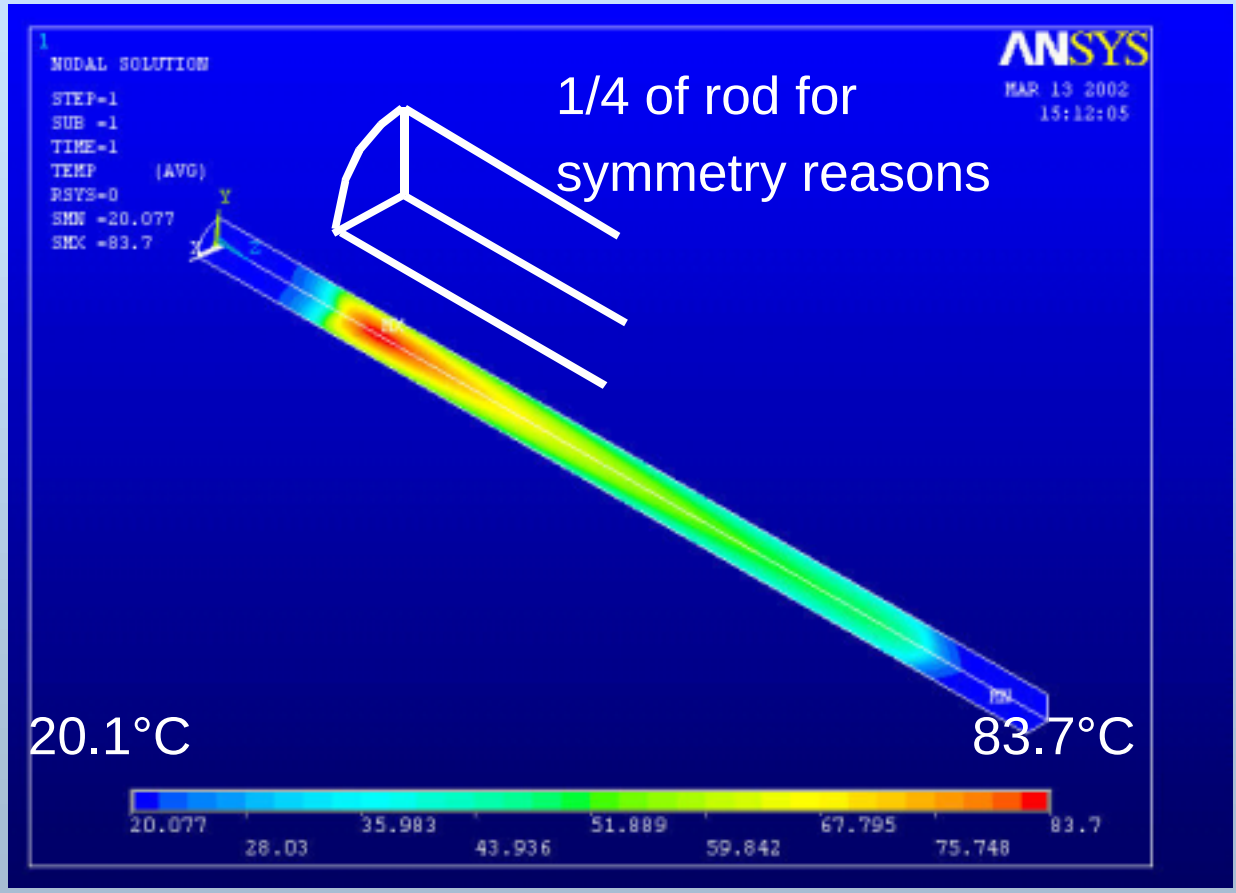
  temperature dependent heat conducitvity

  temperature dependent expansion coefficient

  temperature dependent dn/dT

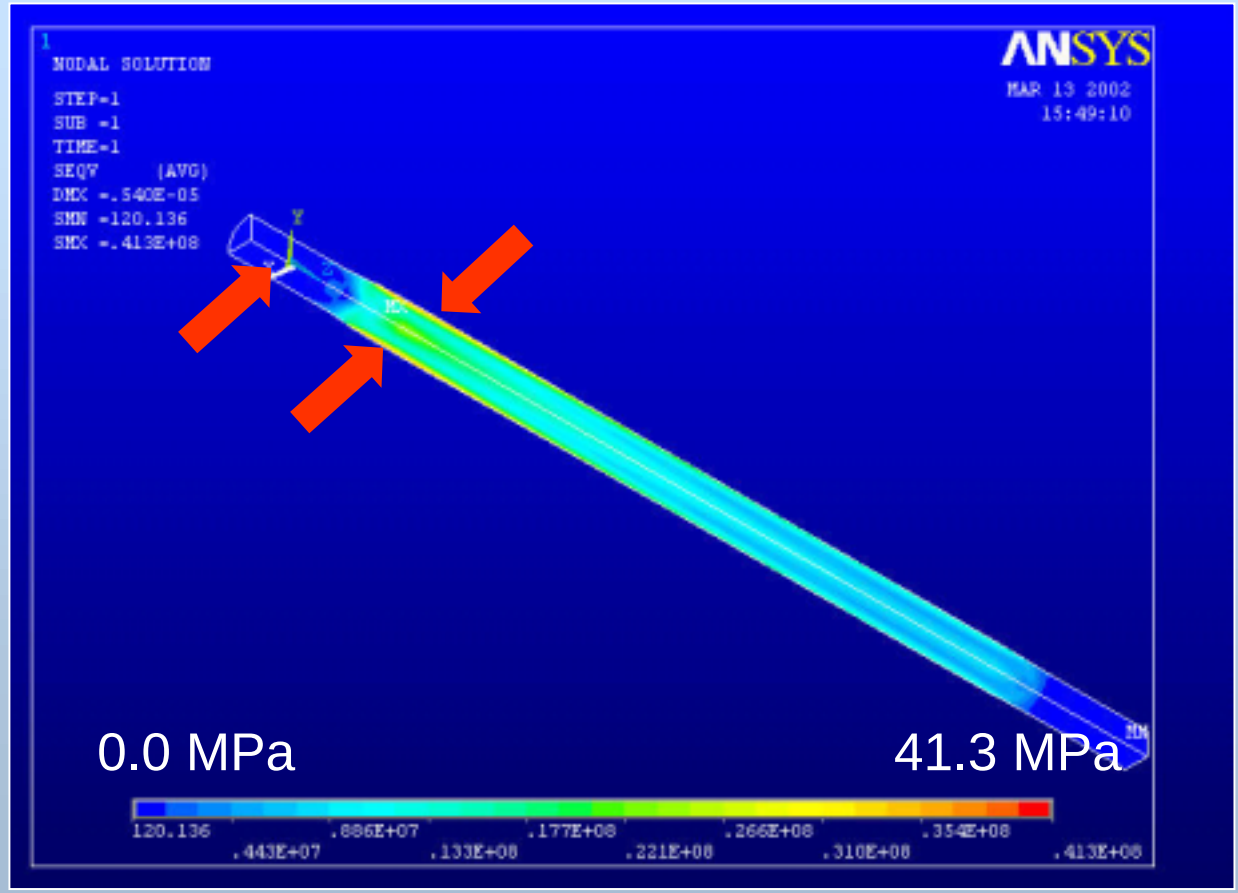
Thermal Modeling/Temperature Distribution

•solution of time independent heat conduction equation by FEM (ANSYS)



Mechanical Stress/Von Mises Equivalent Stress

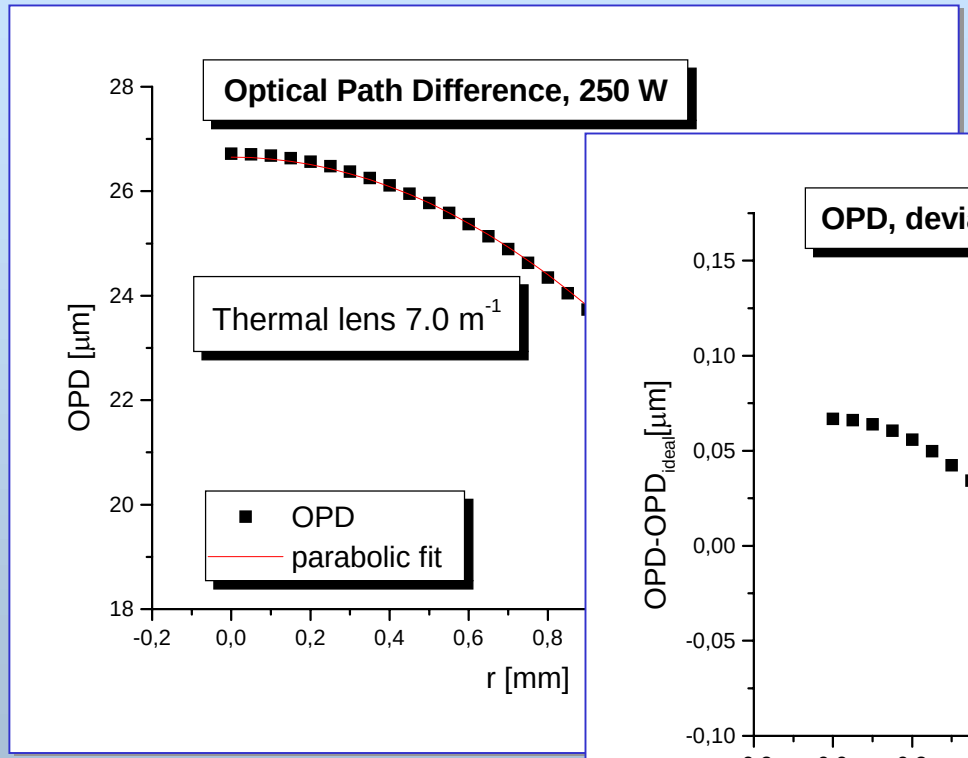
•fracture limit for YAG 130 thru 260 MPa

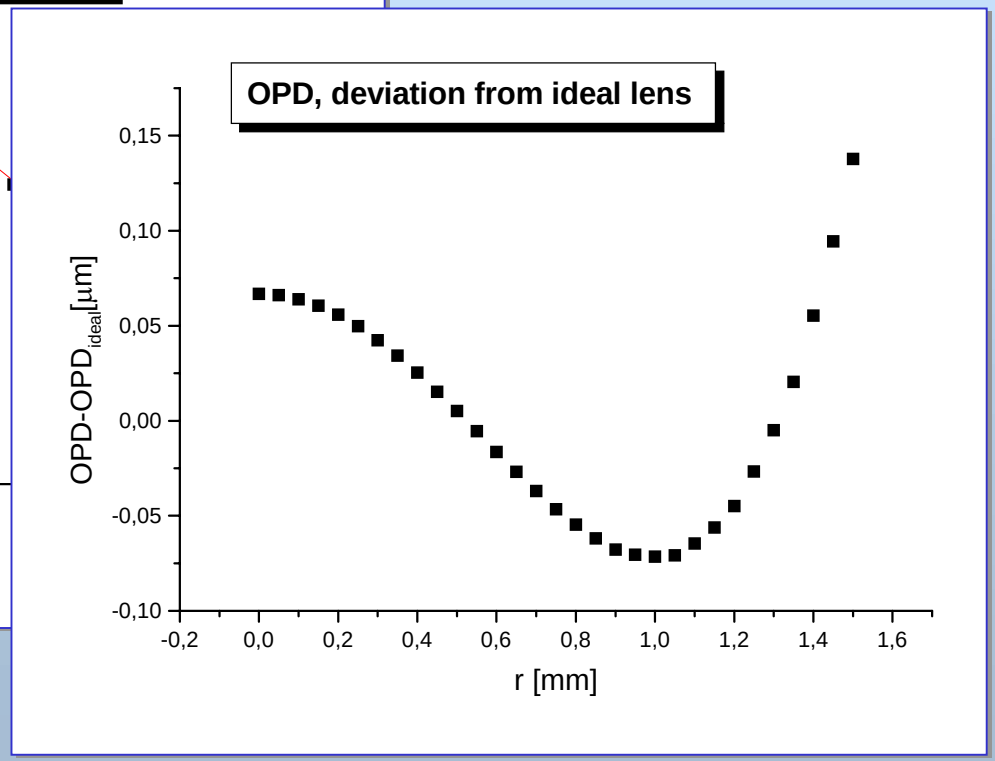


Thermal Lens/Abberations

$$Opt.Path = \int_0^L dz \;\; n(x, y, z; T)$$

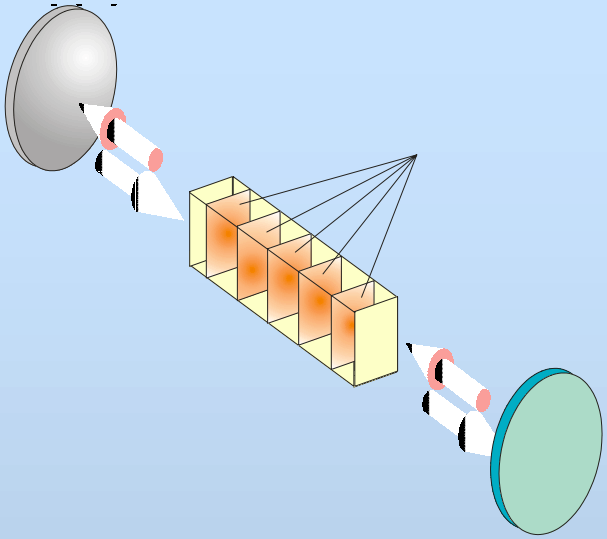
$$D(r) = -\frac{d^2}{dr^2} OPD(r, \phi)$$



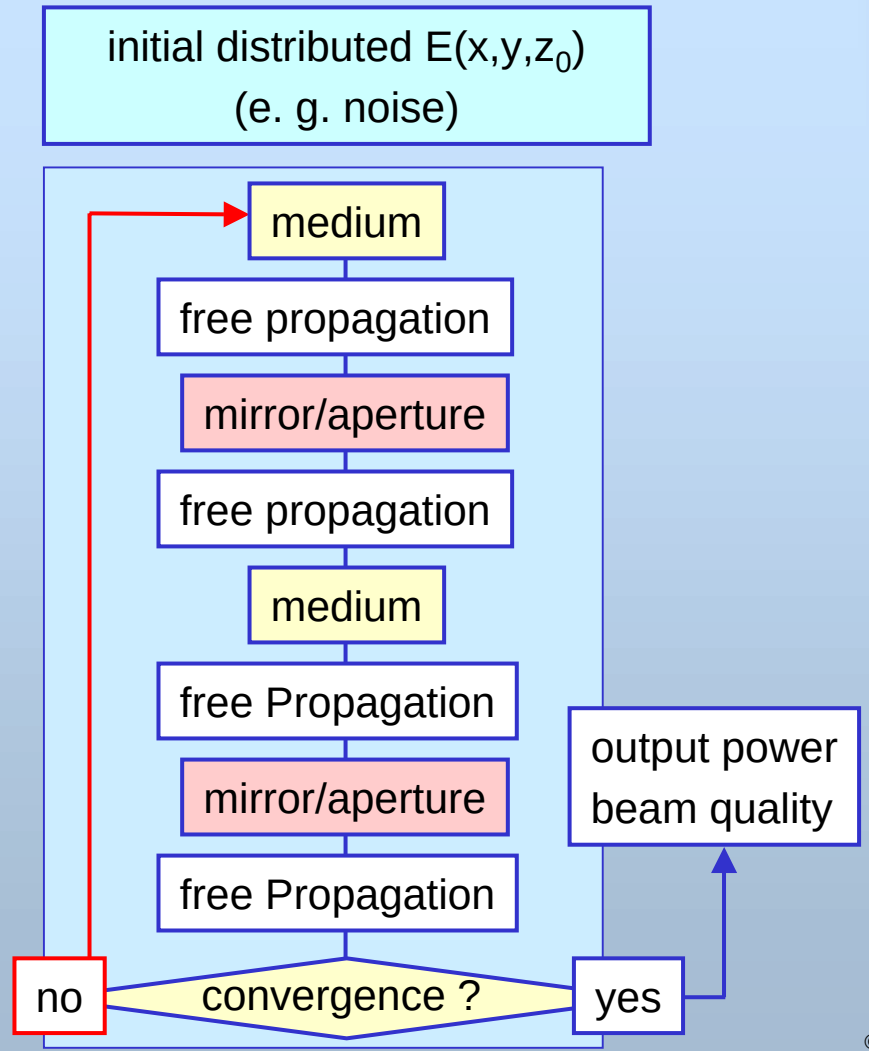


Fox/Li Approach

Iterative Solution of Kirchhoff integral equations



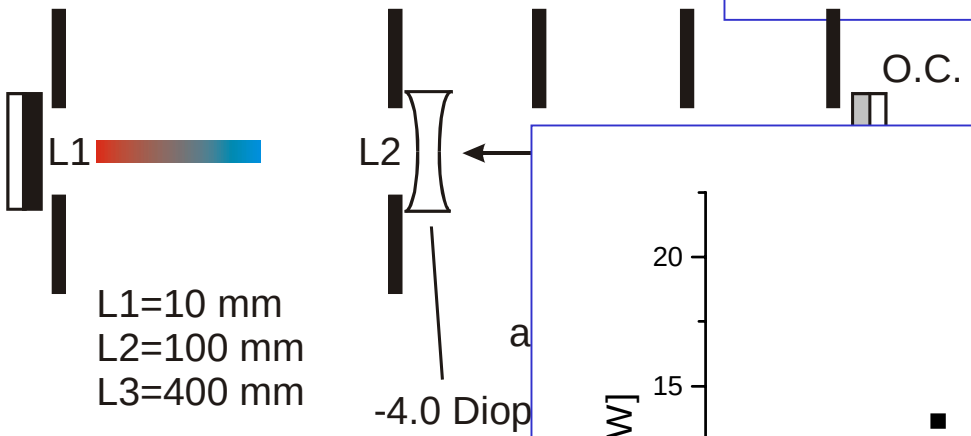
- inhomogenous distributed gain, refractive index, birefringence concentrated in gain/phase sheets
- propagation between gain/phase sheets and in free space described by FFT propagator

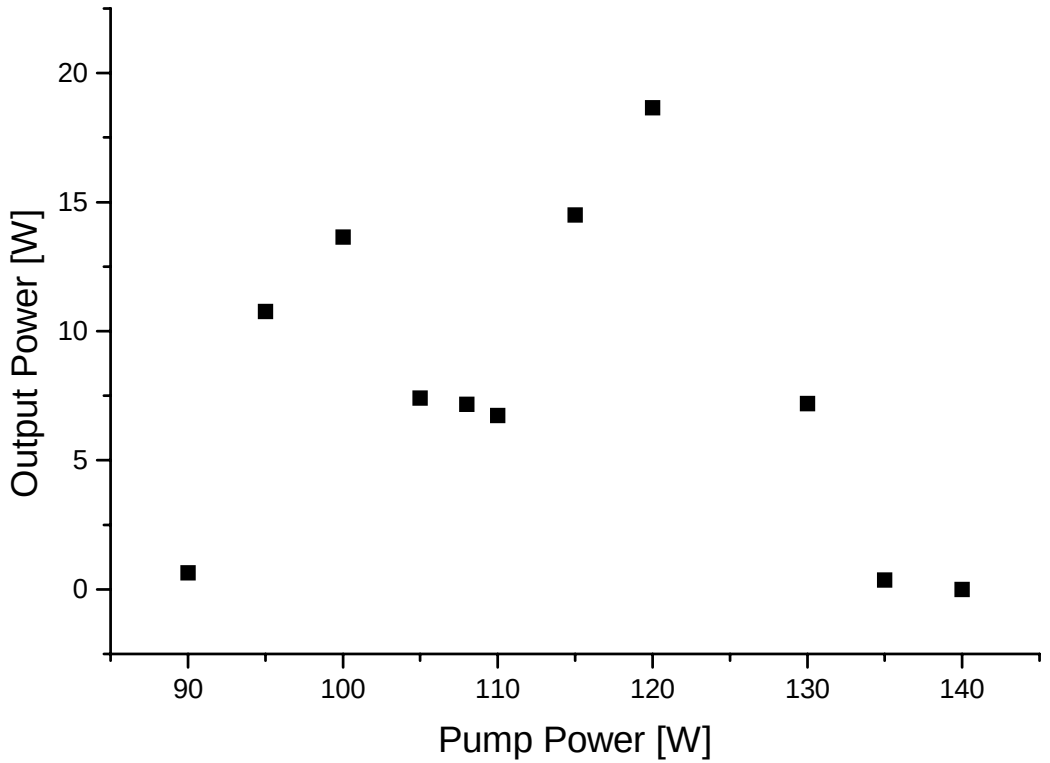


First Results

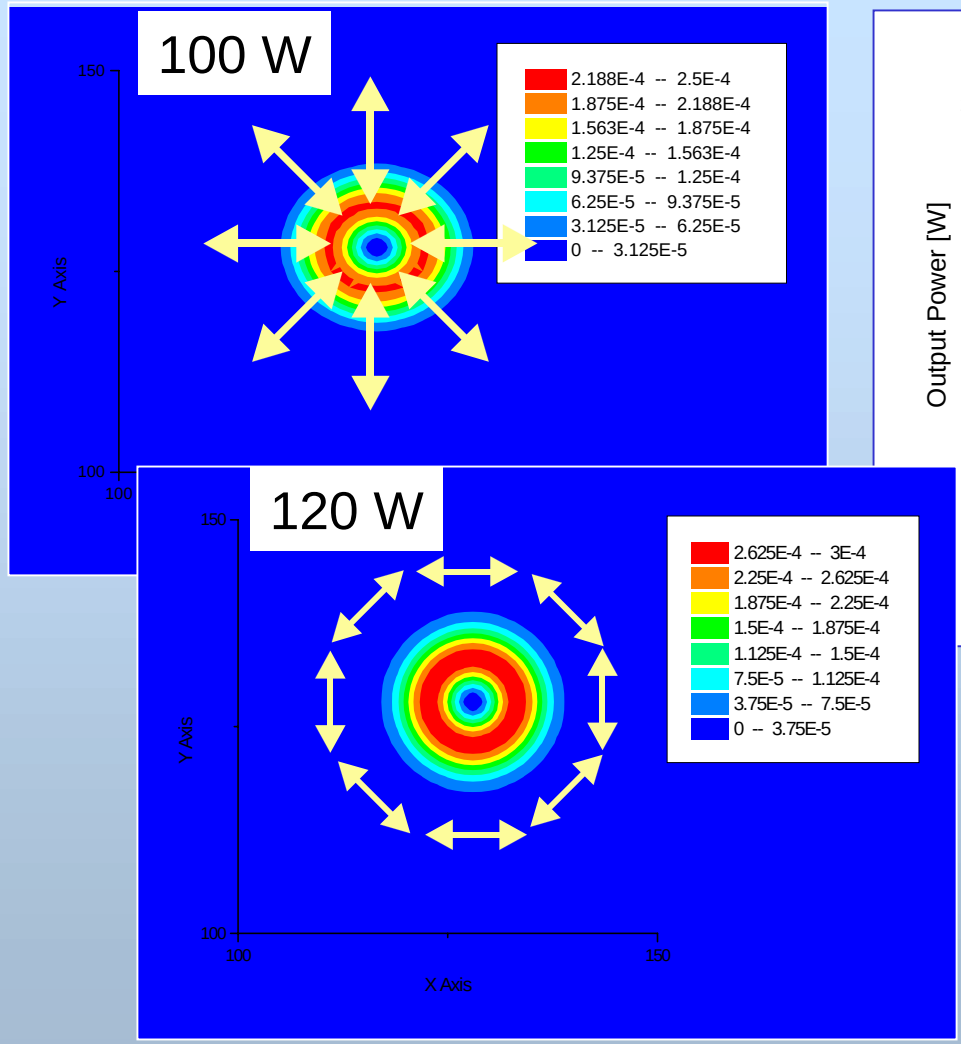
test resonator (plane-plane)

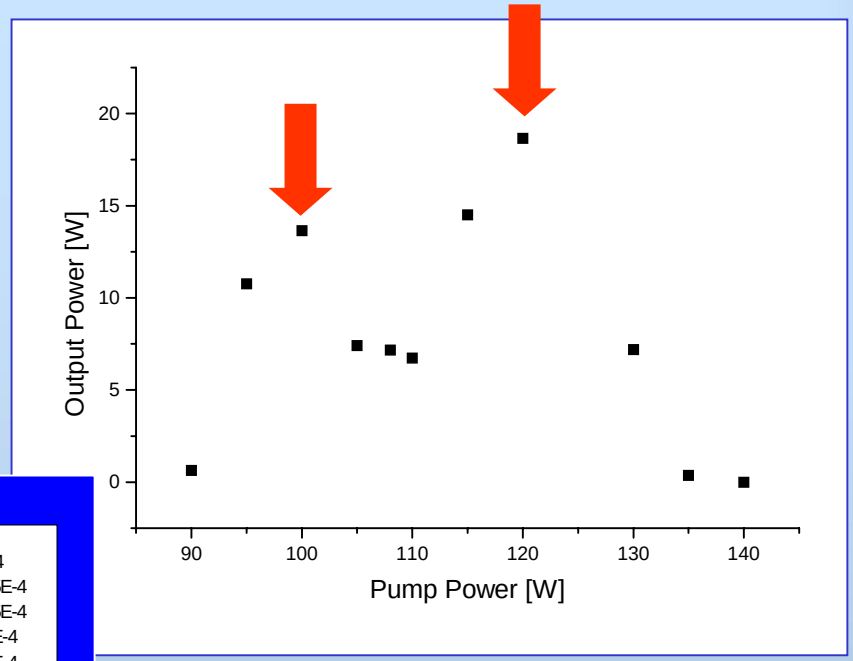
•mode diameter in rod 1 mm





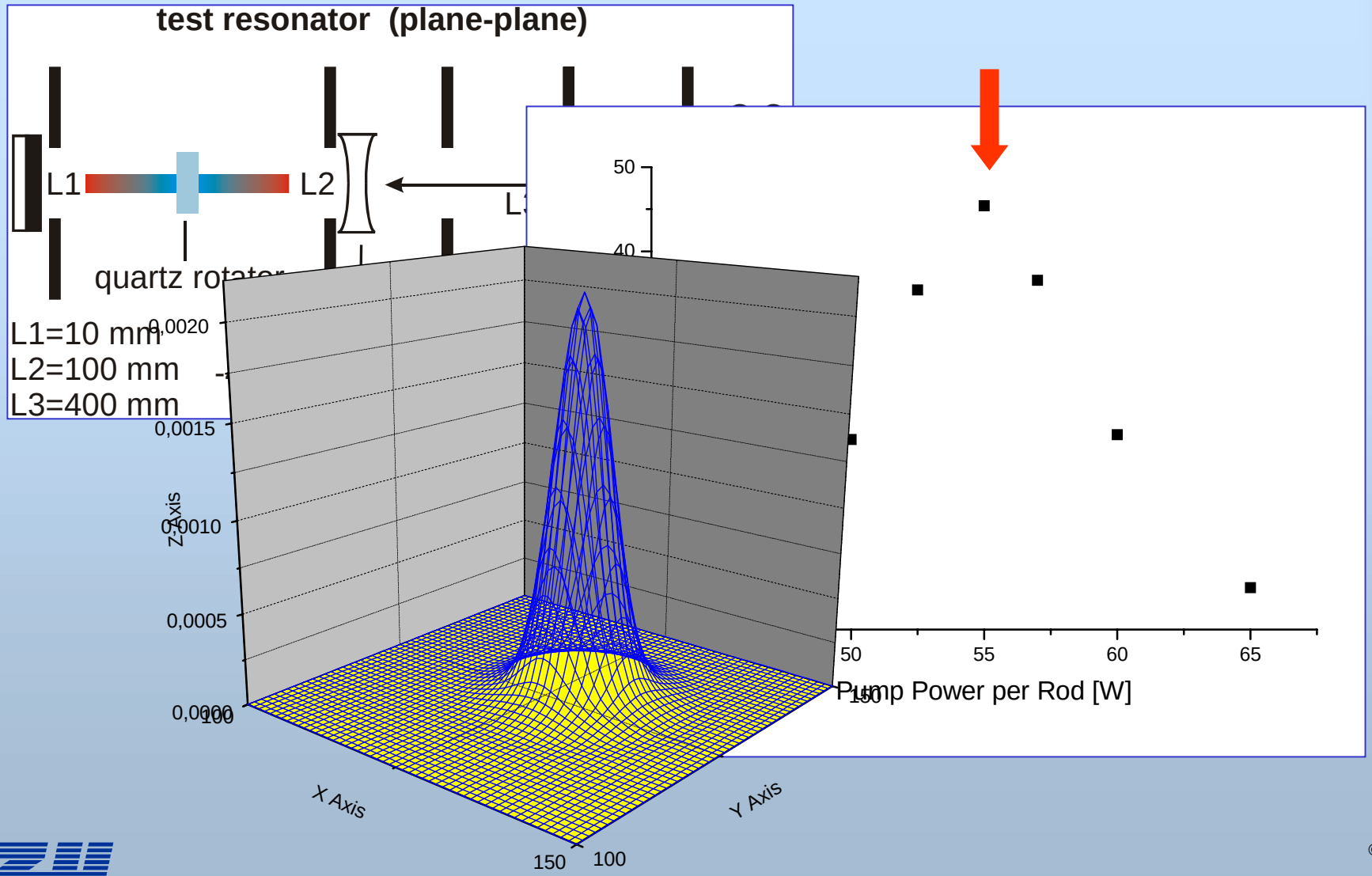
First Results



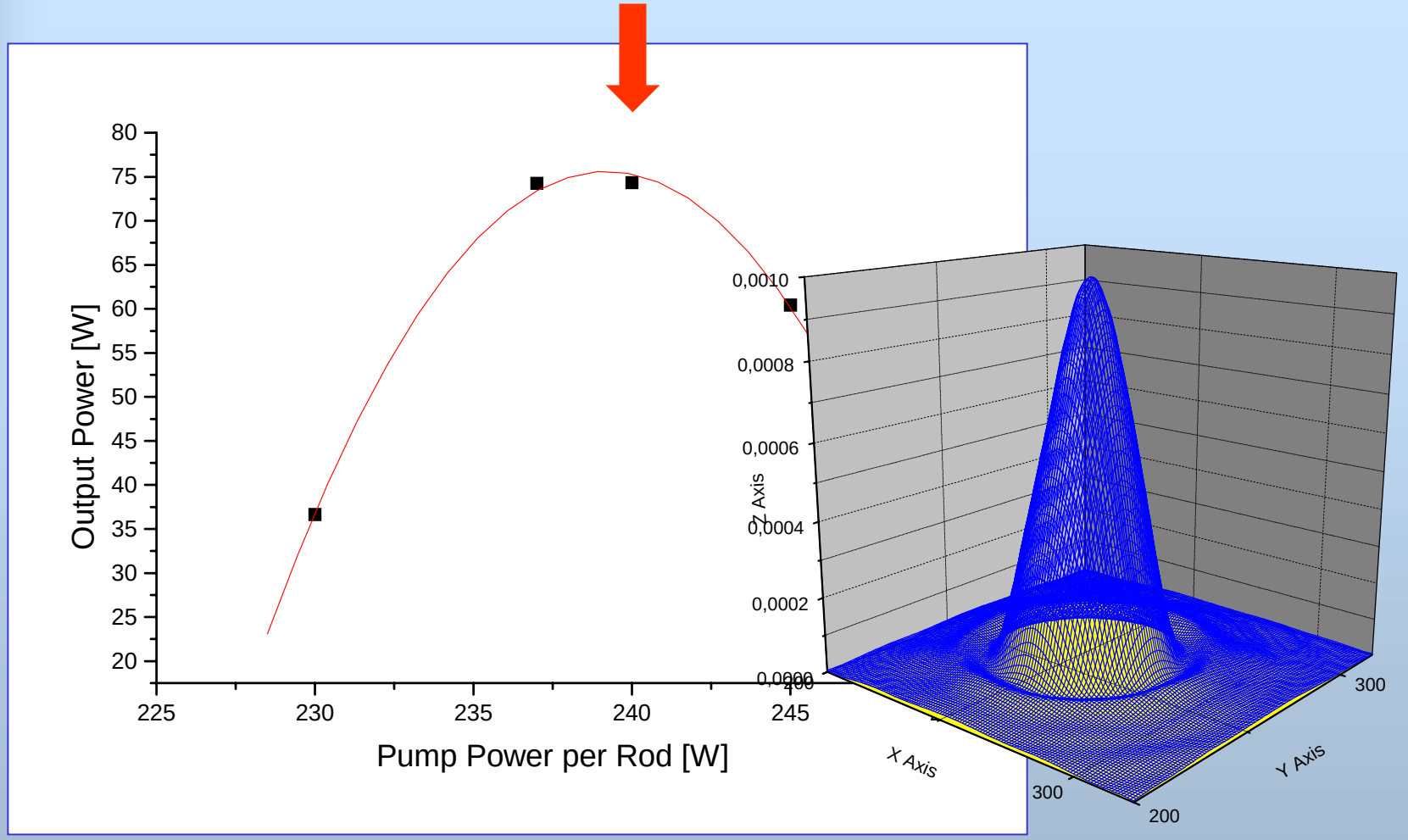


•polarisation eigenstates

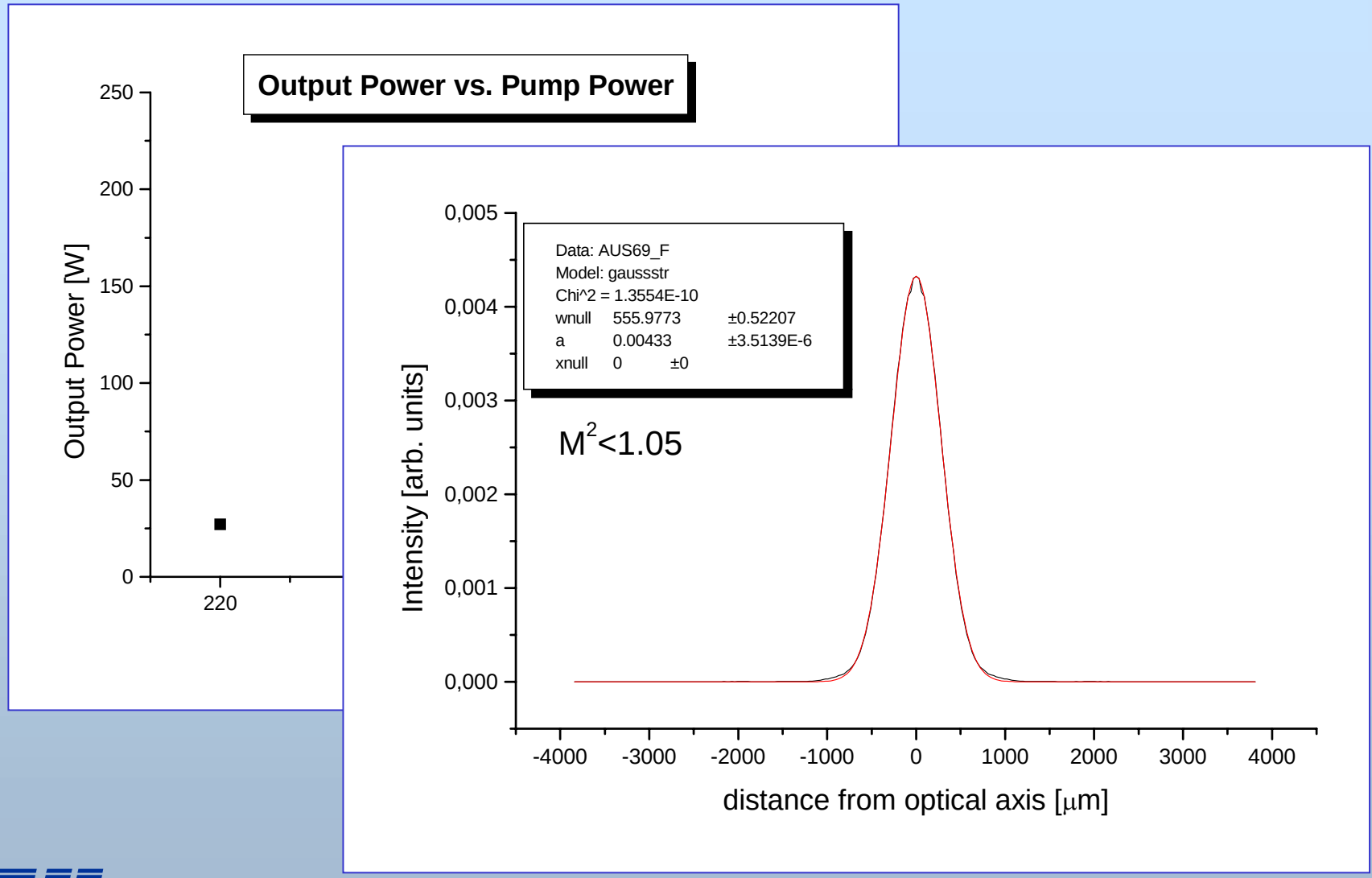
First Results/Birefringence Compensation



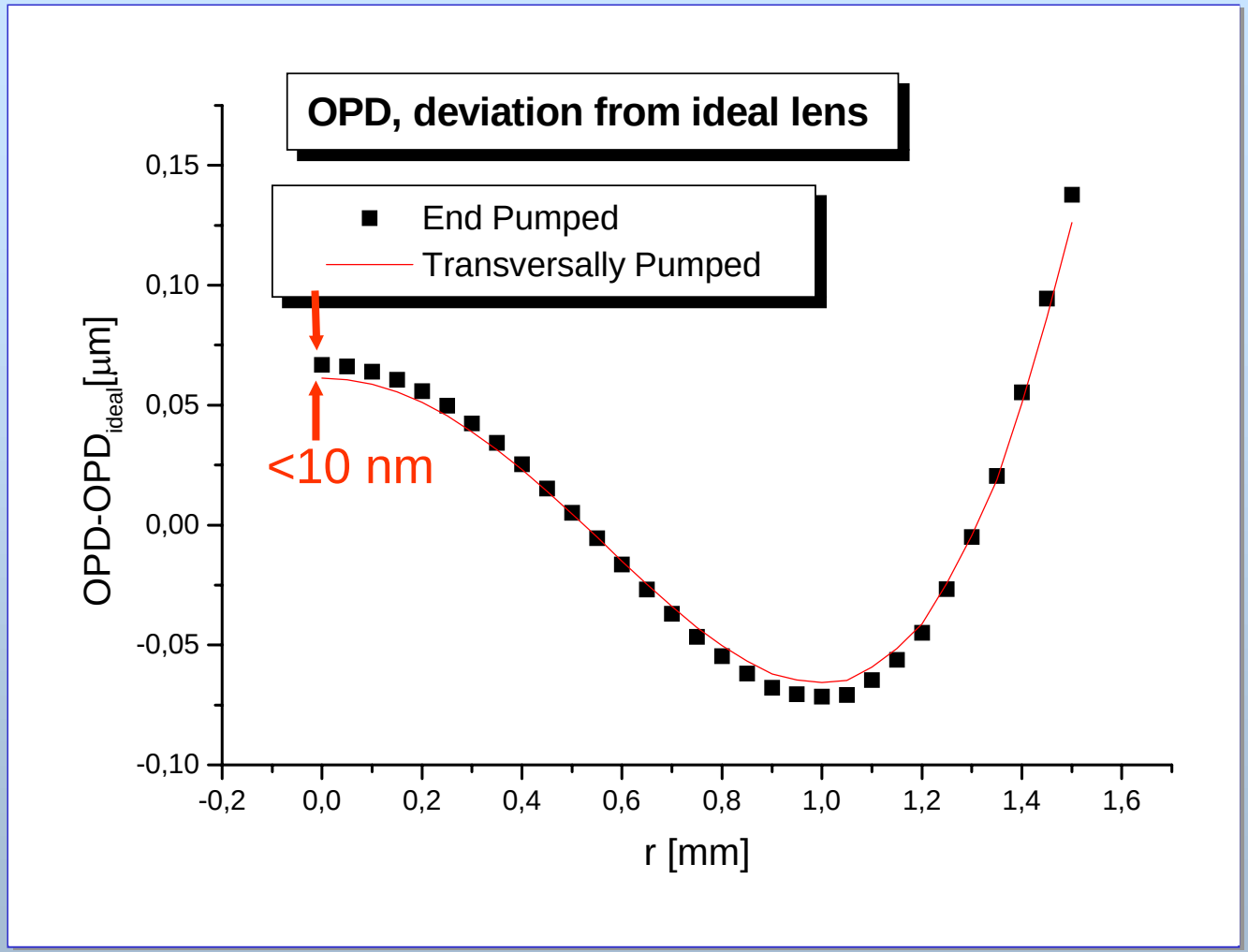
First Results/100 W Head



First Results/100 W Head w/o Abberations

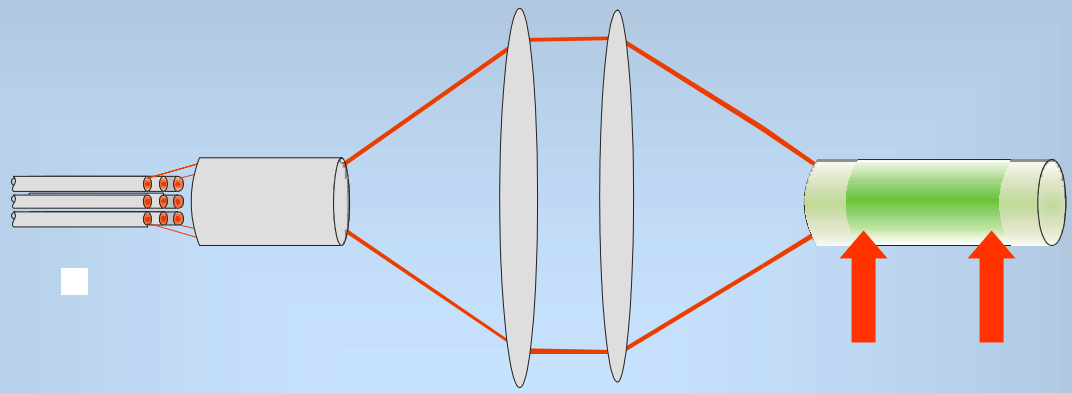


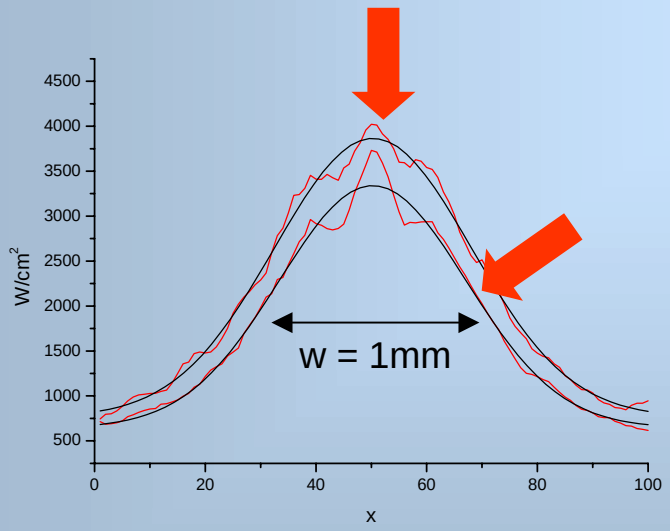
Abberations/End Pumped vs. Transversally Pumped

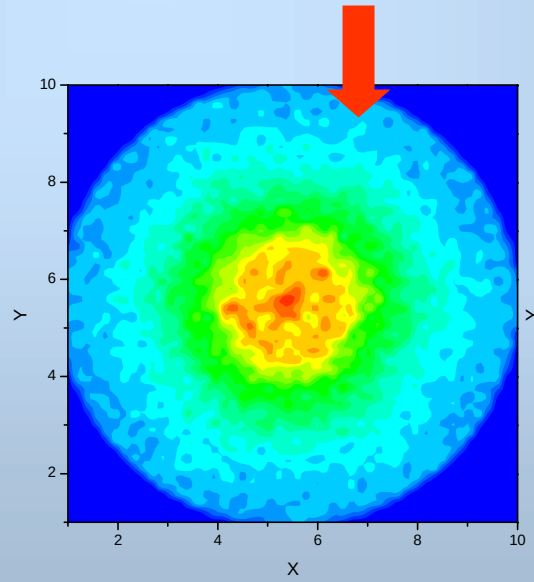


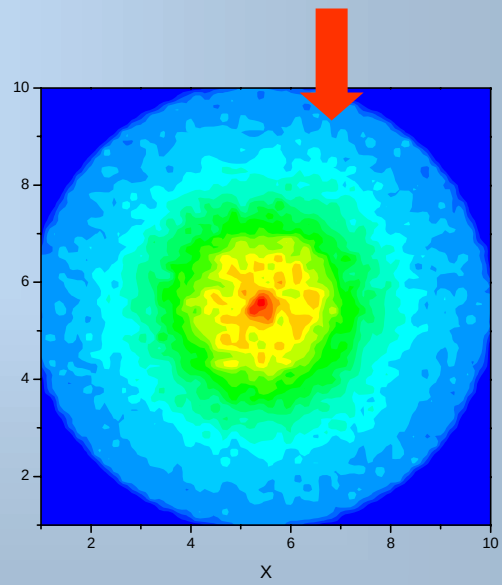
Pump Concepts

mode selective pumping



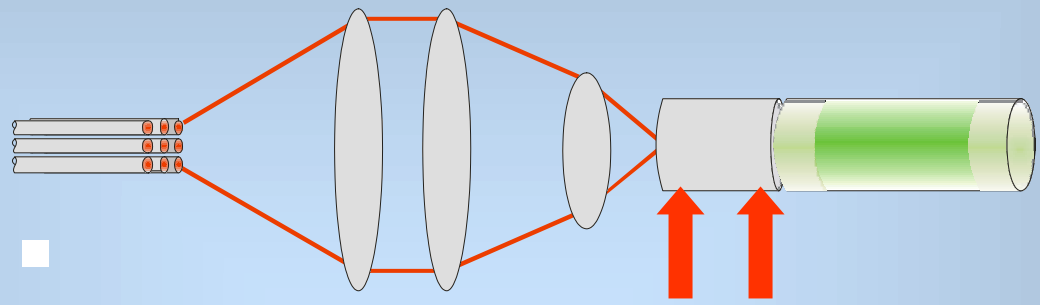


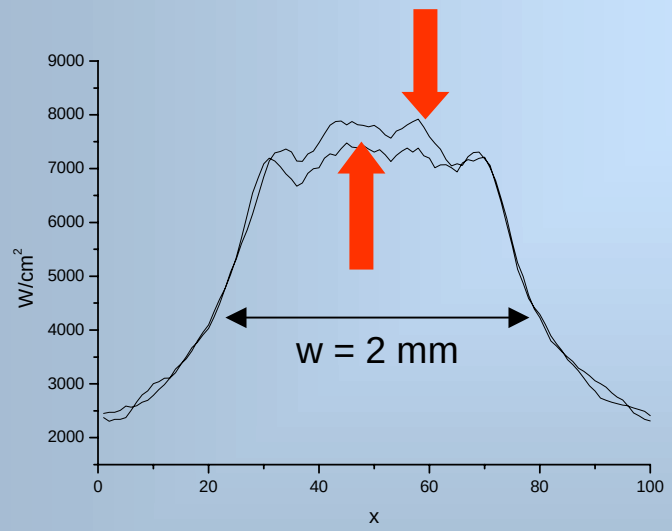


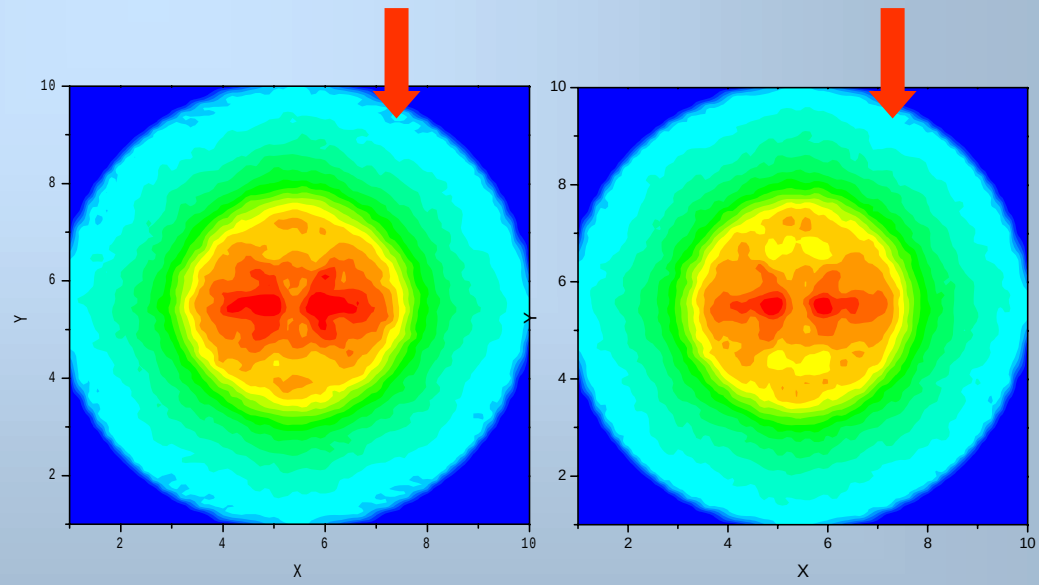


Pump Concepts

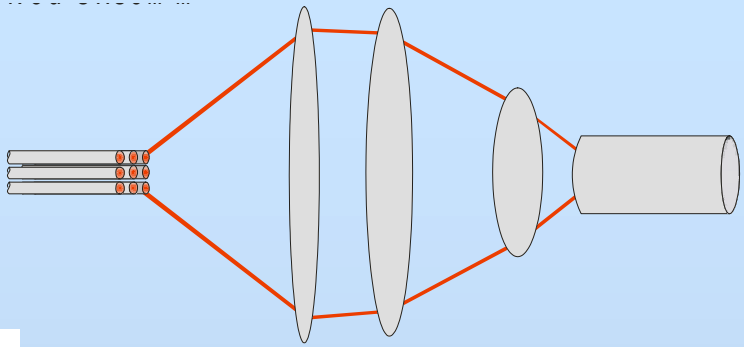
mode selective pumping





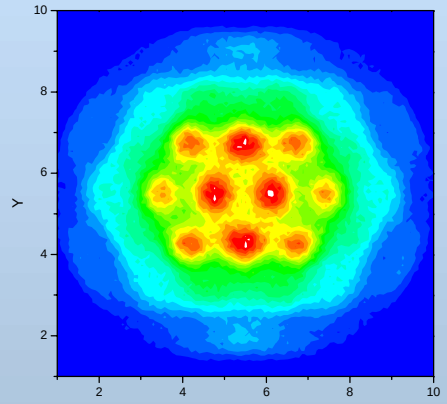


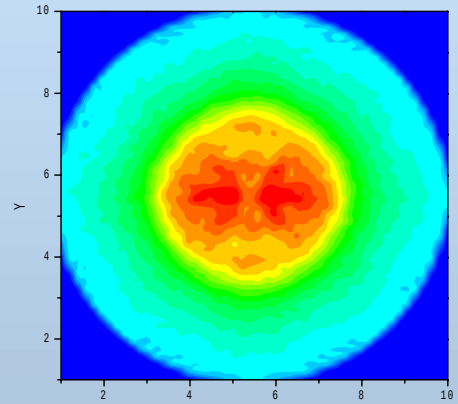
Homogenization of Pump Light



simulation

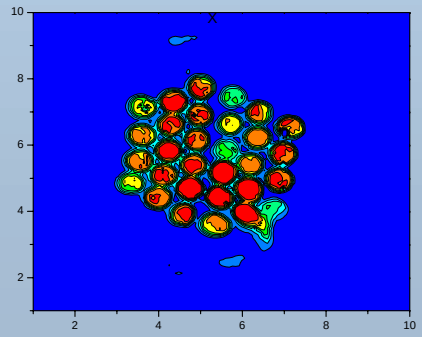
10 x 800 µm

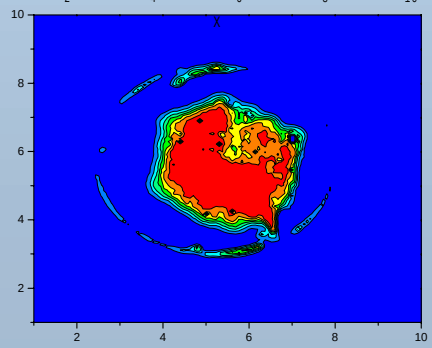




measured

30 x 800 µm

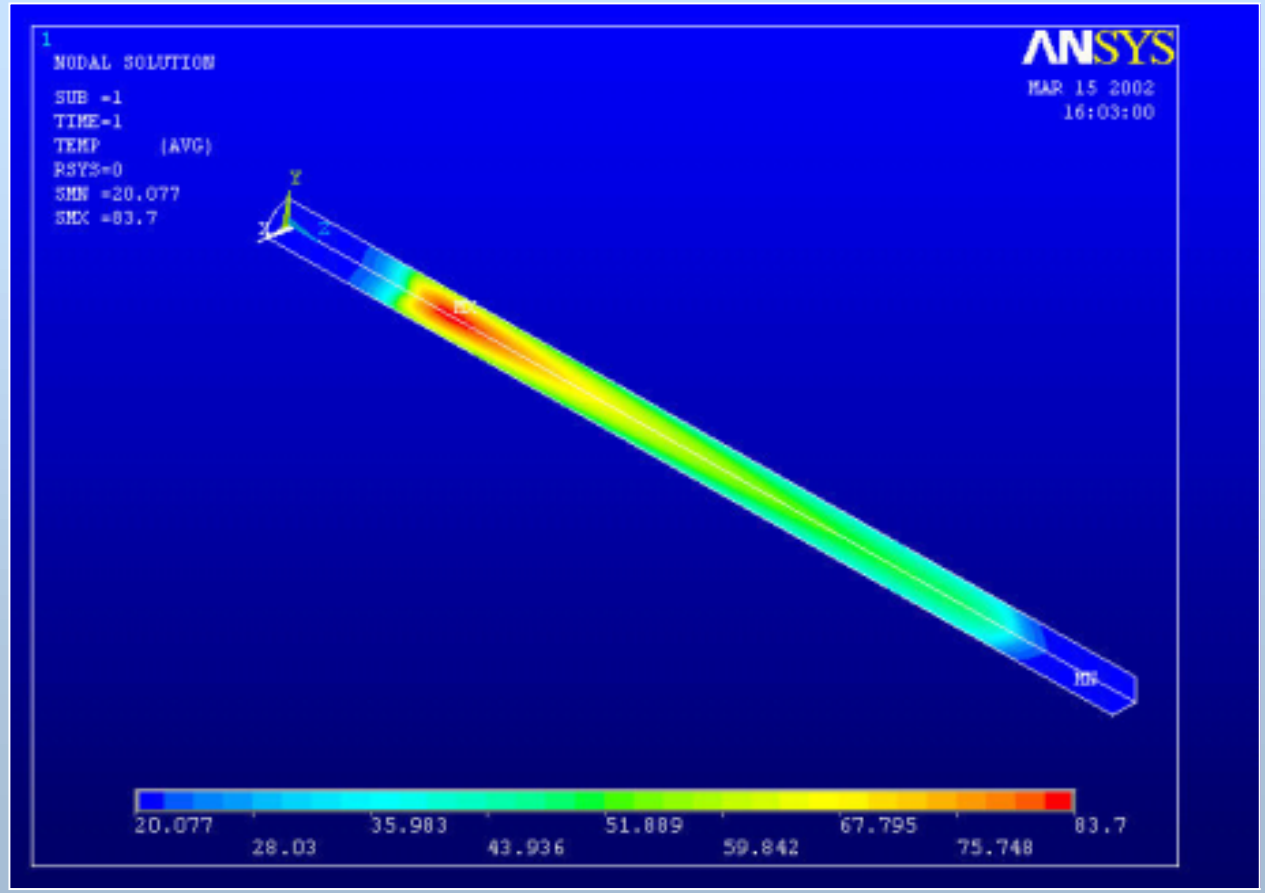




Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

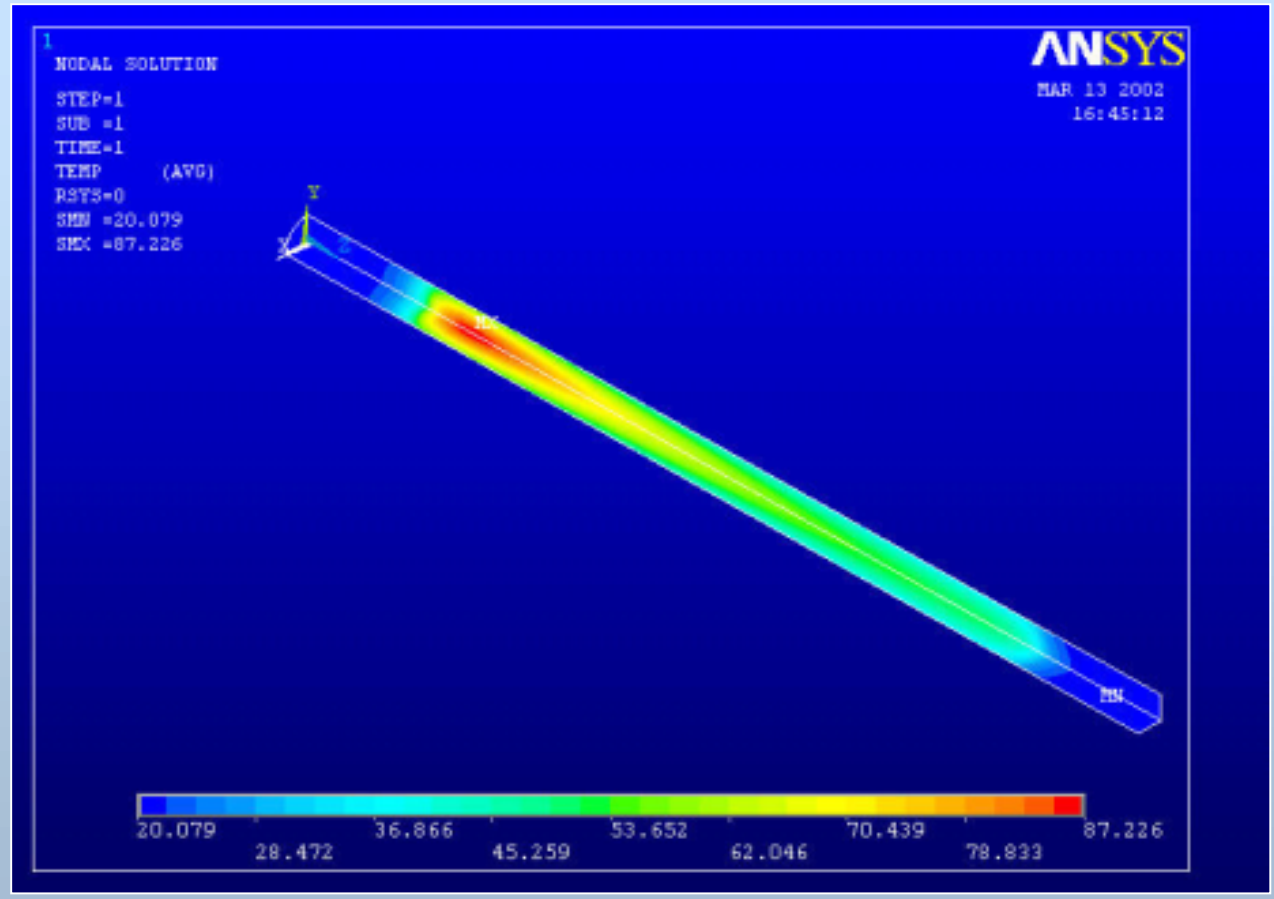
5000 μm



Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

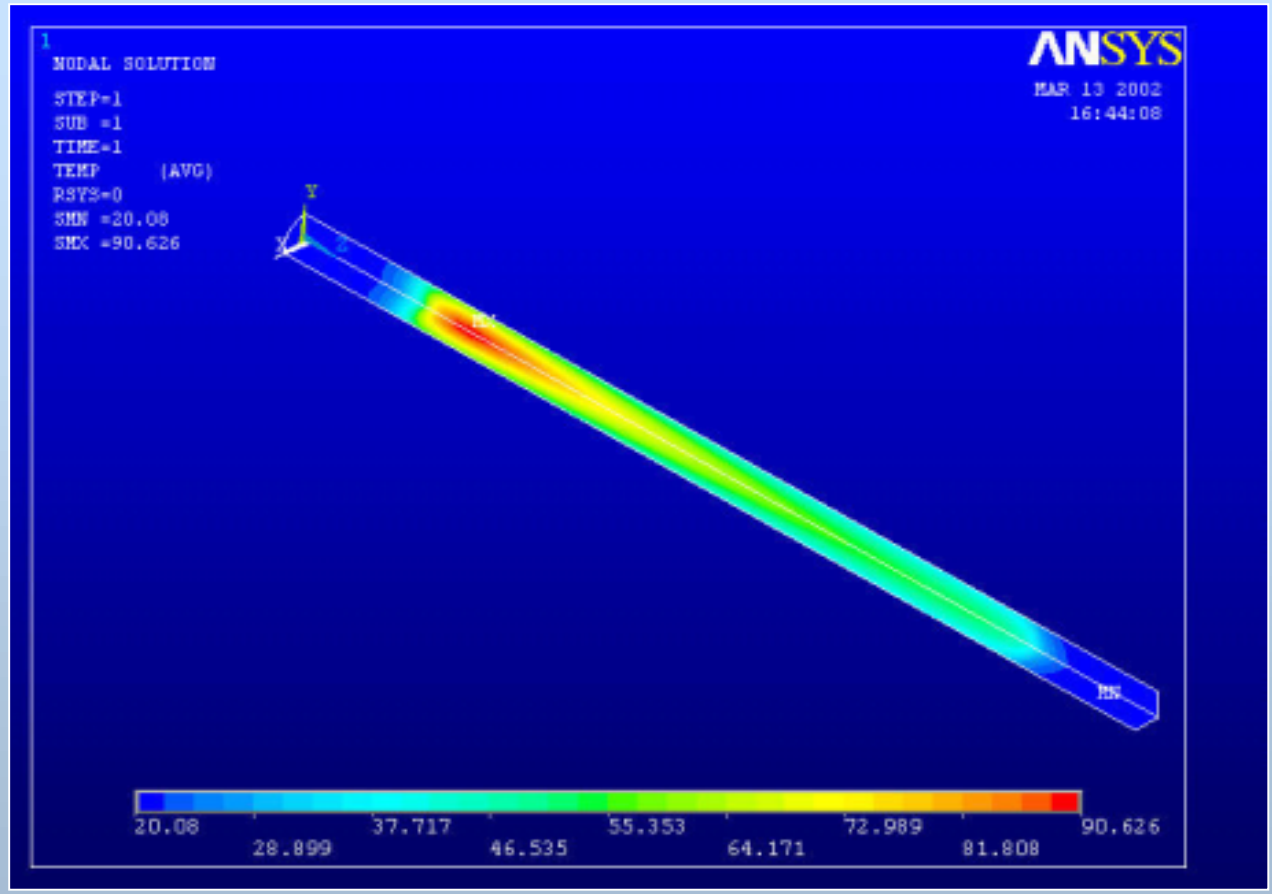
2000 μm



Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

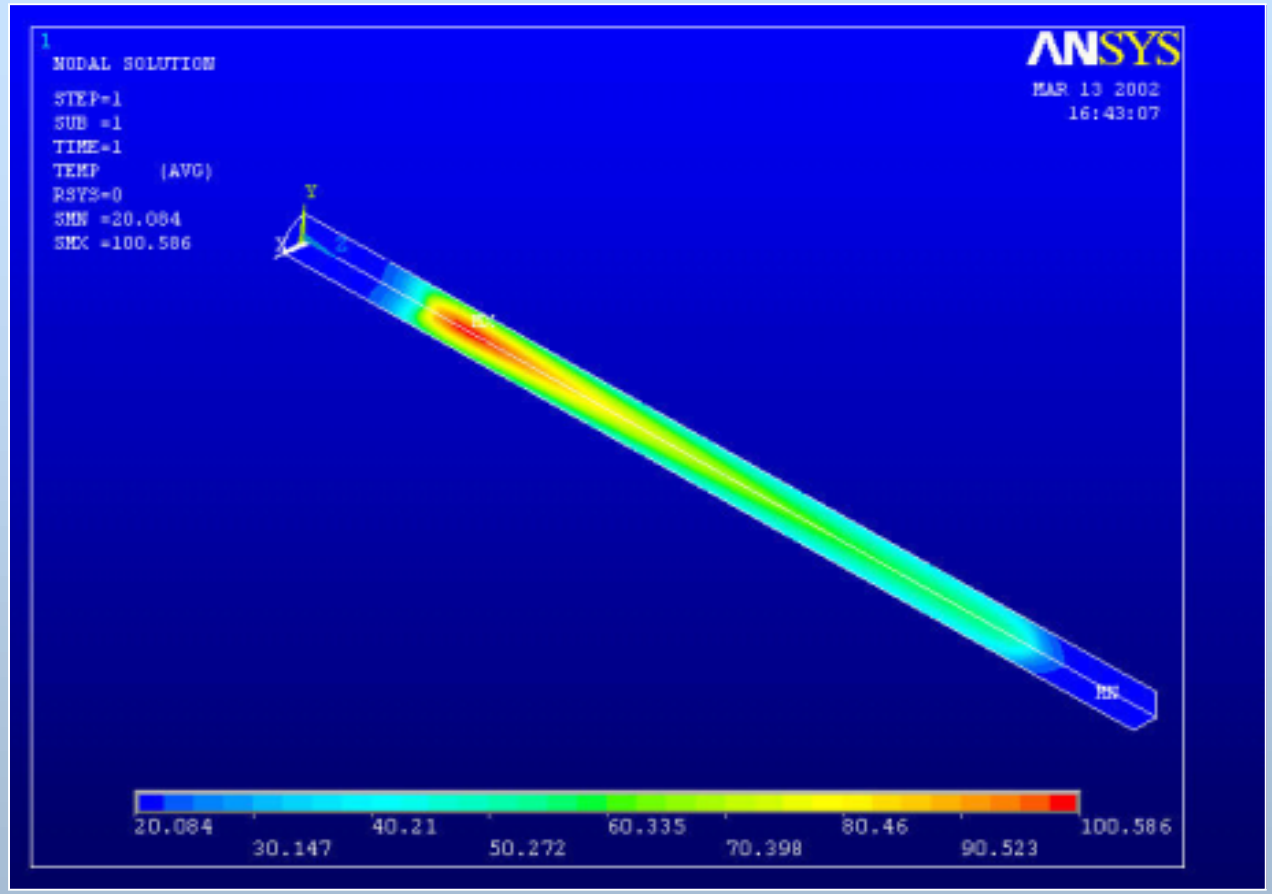
1500 µm



Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

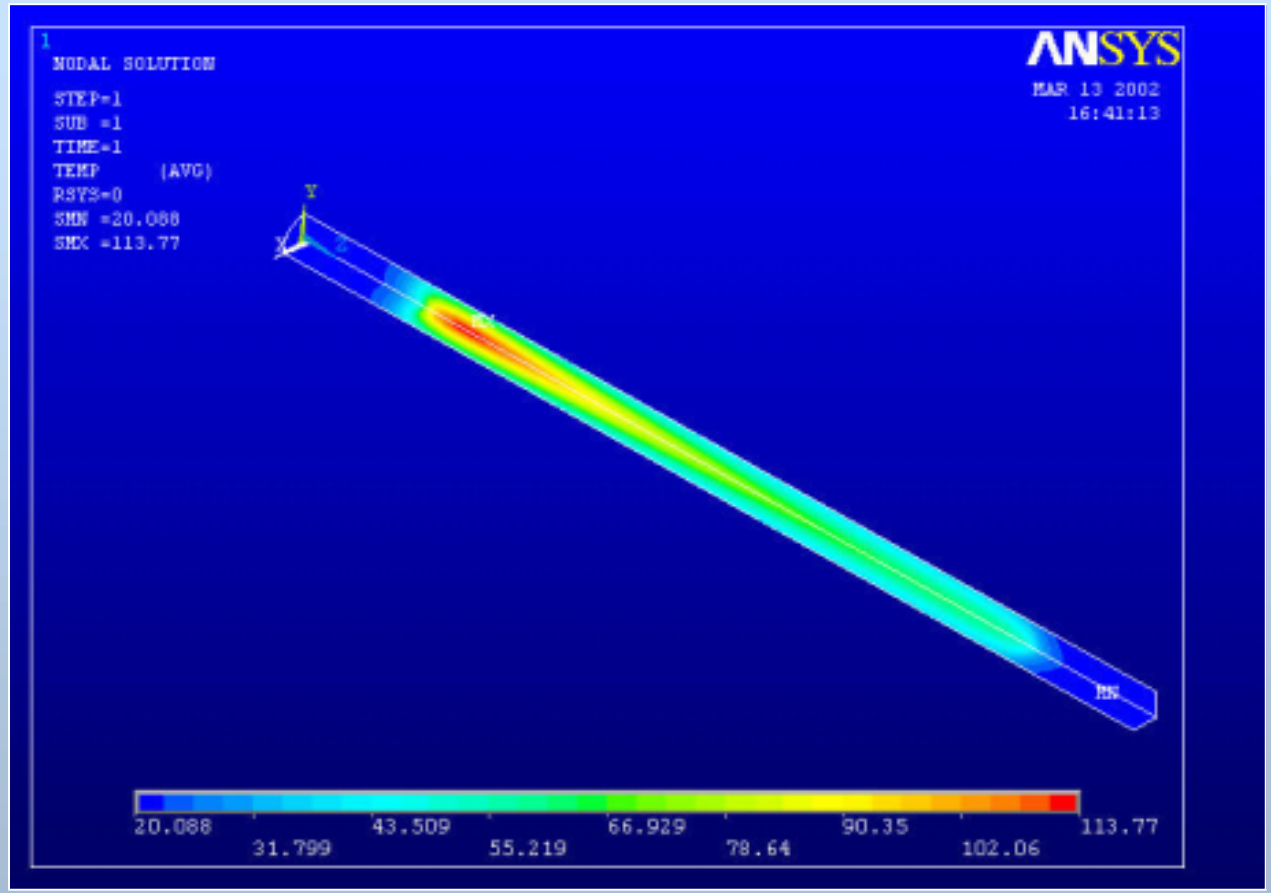
1000 μm



Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

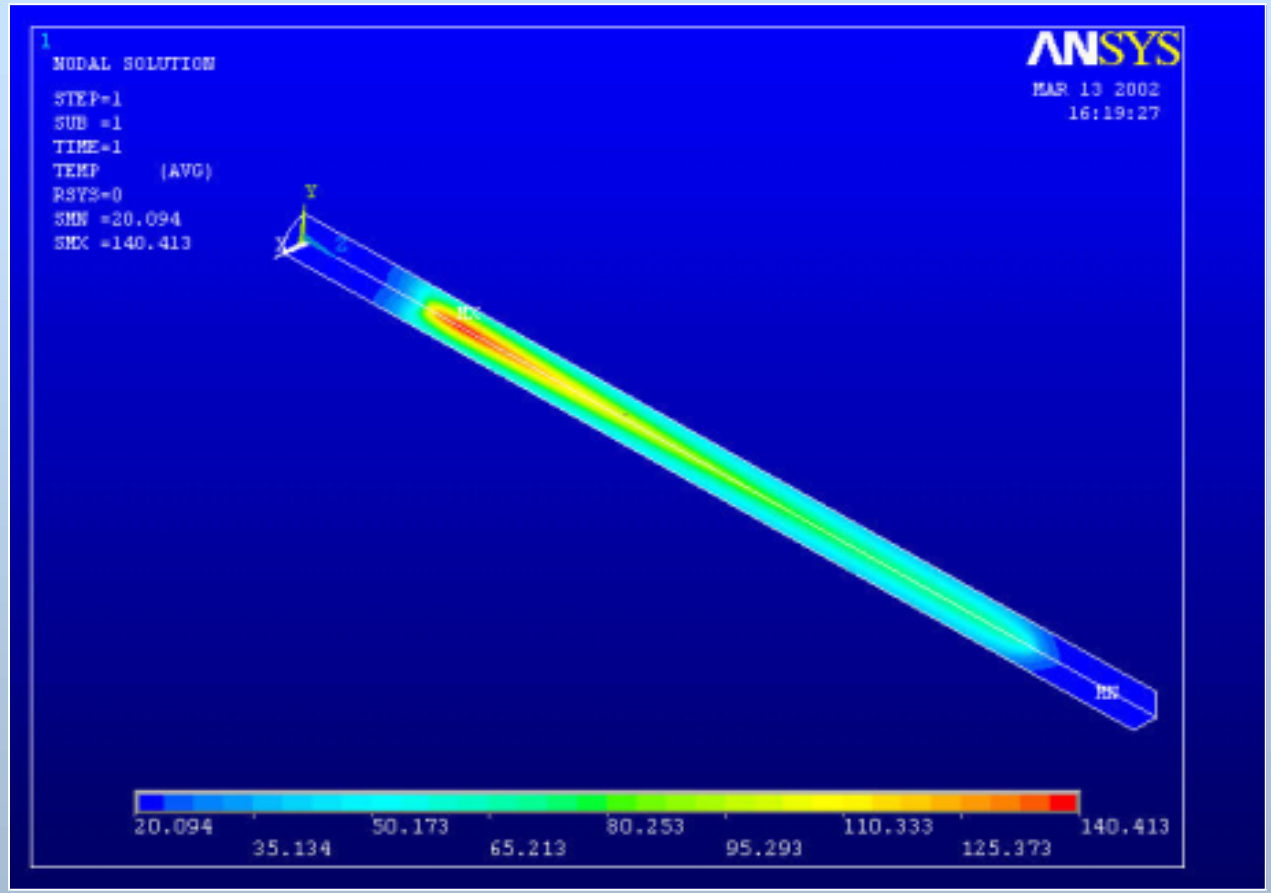
750 μm



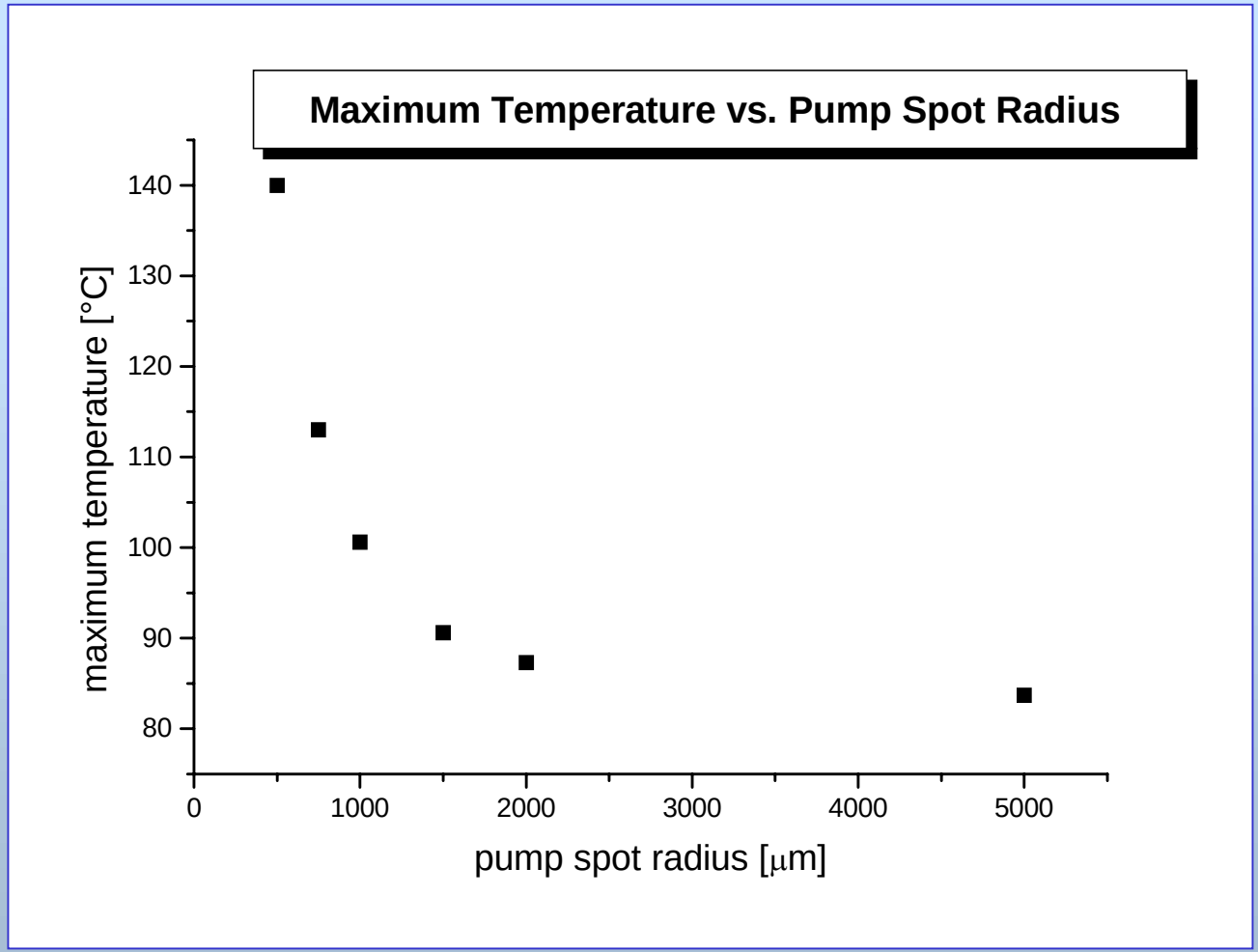
Thermal Modeling/Temperature Distribution

varying with pump spot diameter (pump power kept constant)

500 μm



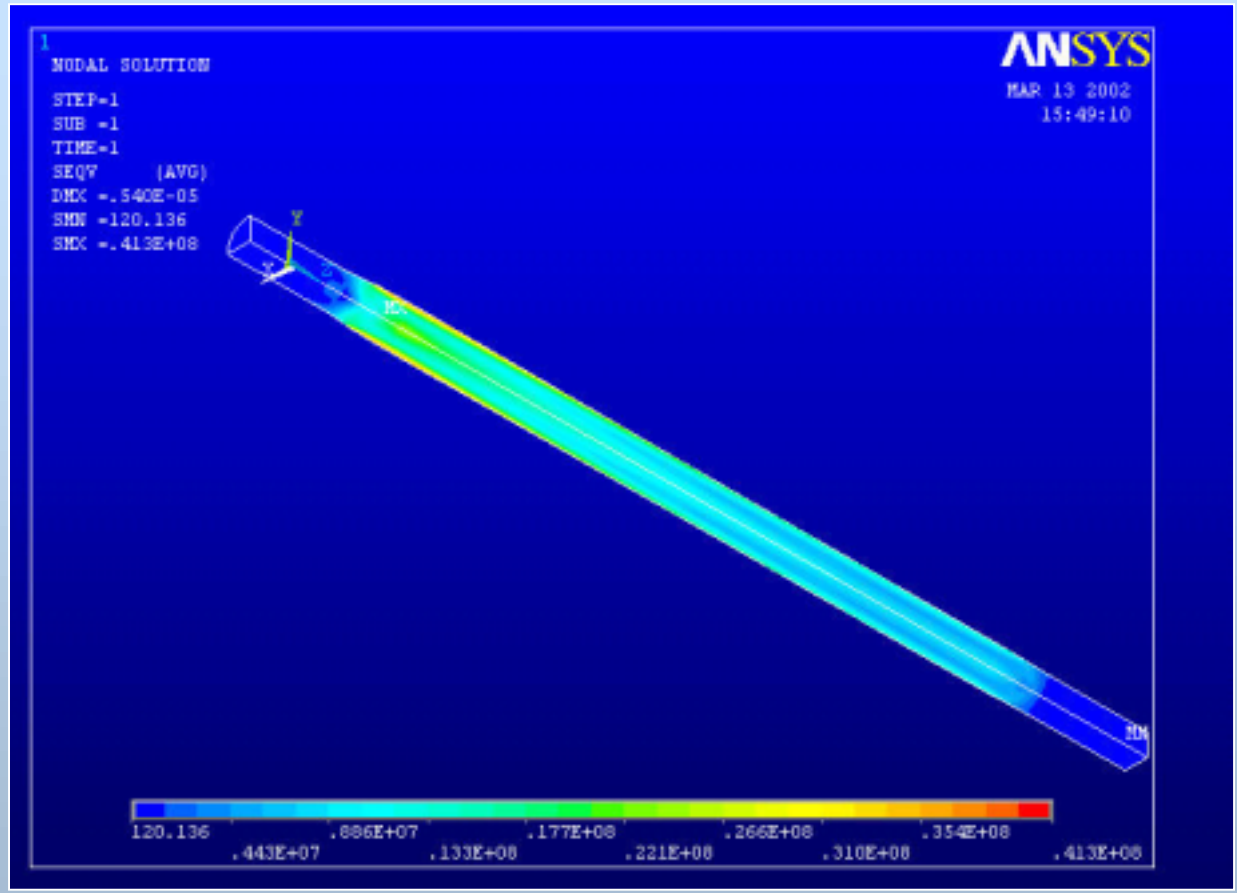
Thermal Modeling/Maximum Temperature



Von Mises Stress

varying with pump spot diameter (pump power kept constant)

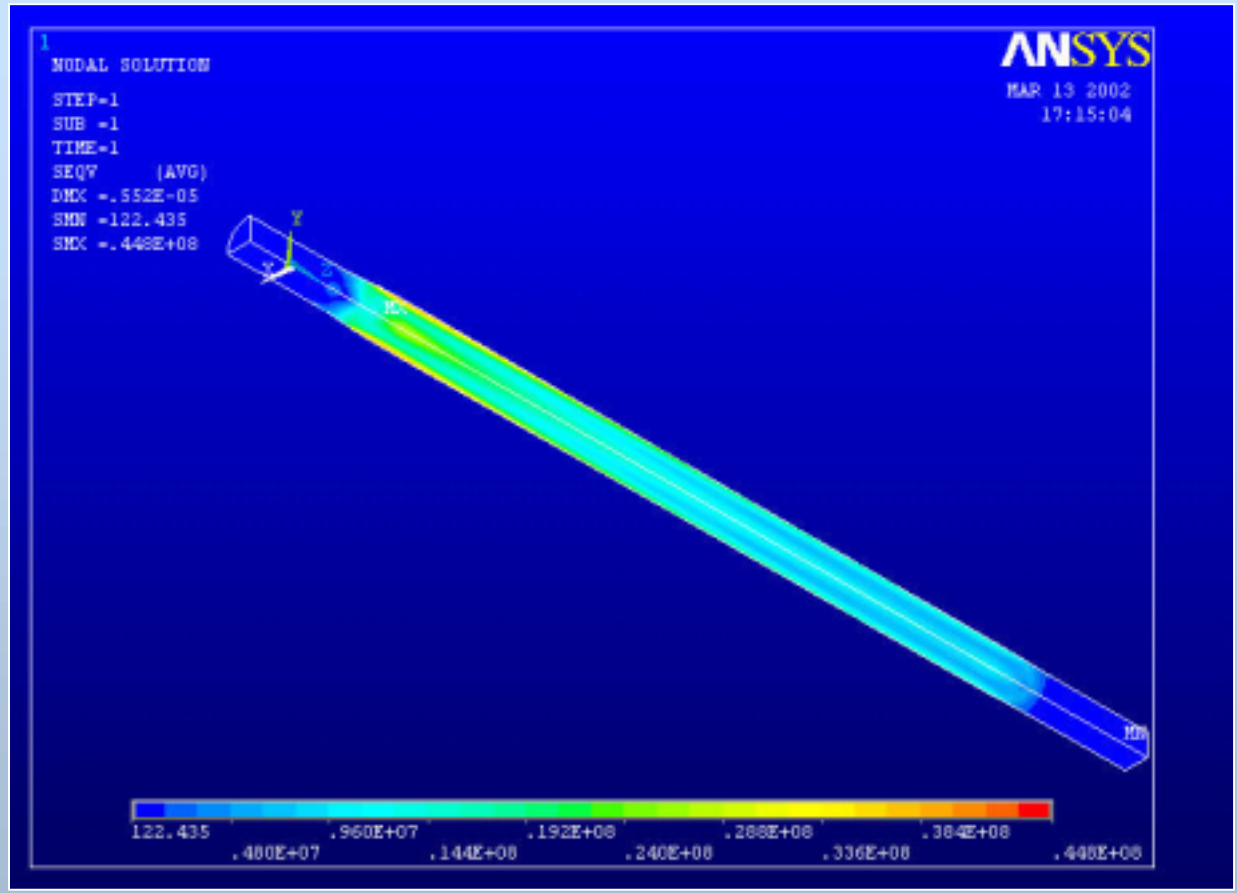
5000 μm



Von Mises Stress

varying with pump spot diameter (pump power kept constant)

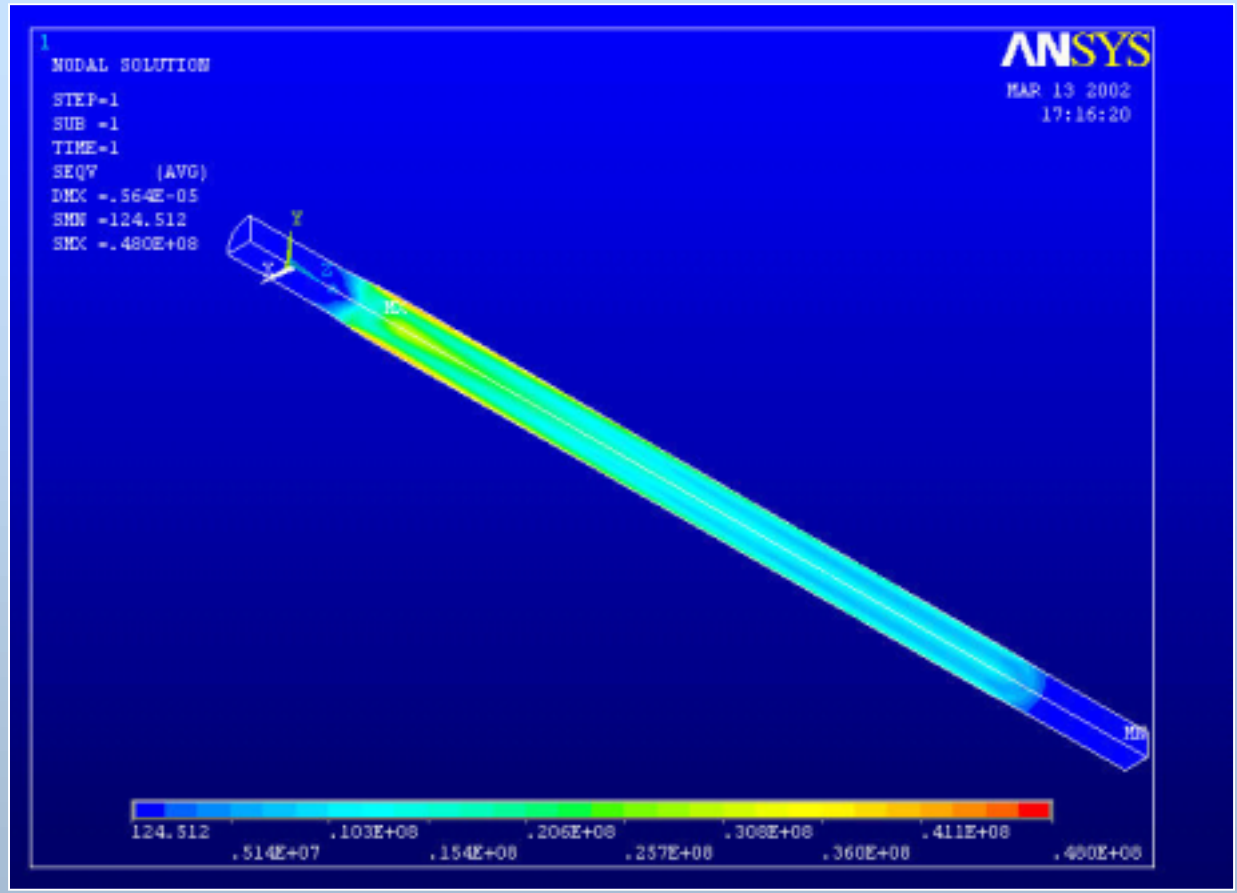
2000 μm



Von Mises Stress

varying with pump spot diameter (pump power kept constant)

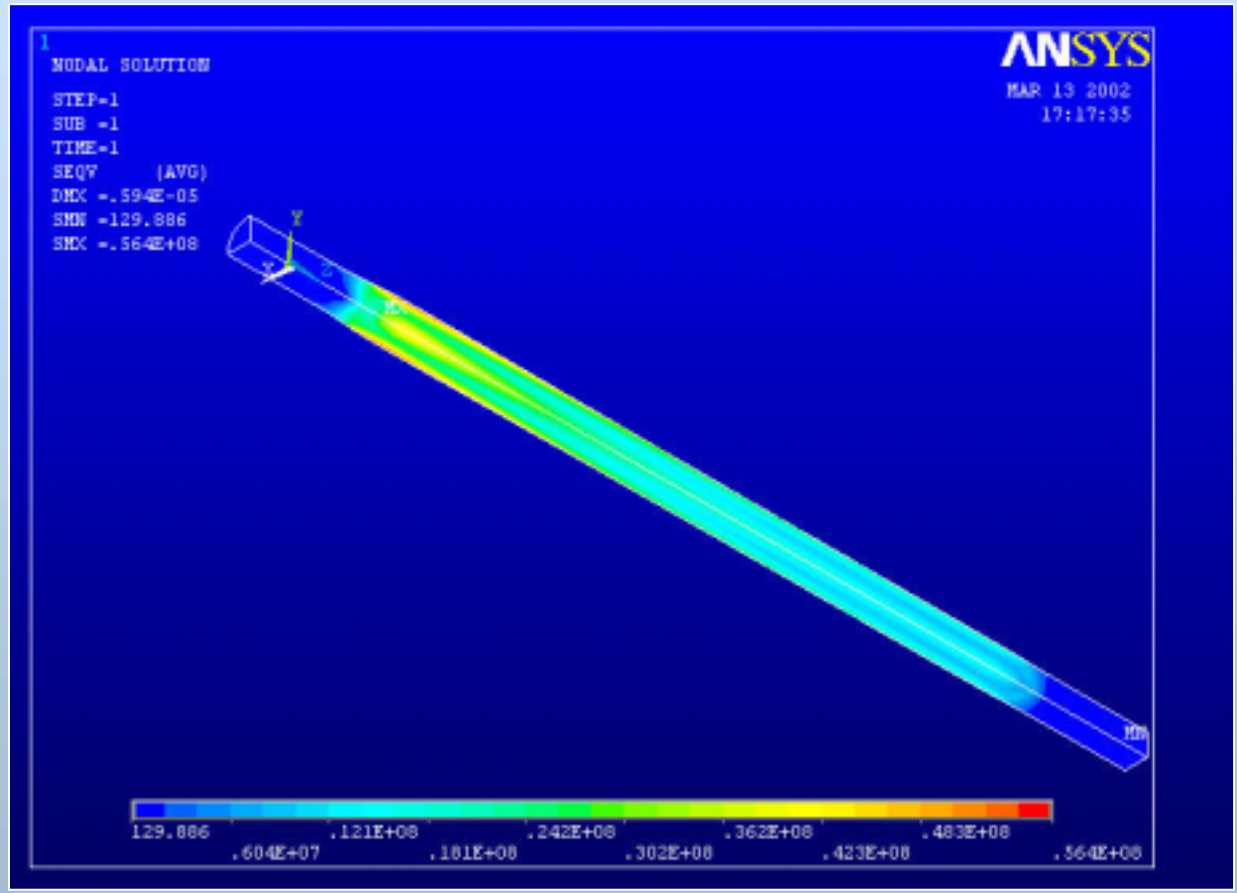
1500 μm



Von Mises Stress

varying with pump spot diameter (pump power kept constant)

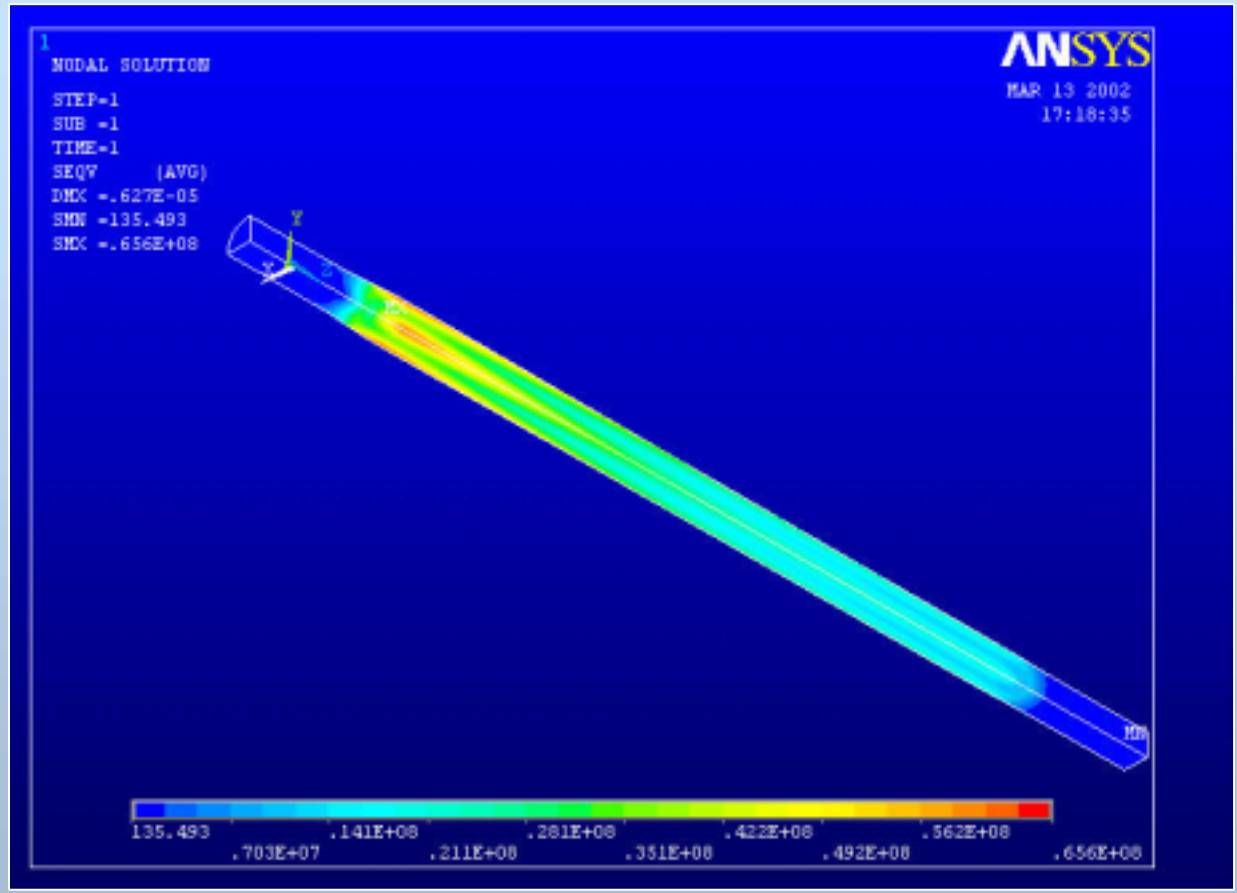
1000 μm



Von Mises Stress

varying with pump spot diameter (pump power kept constant)

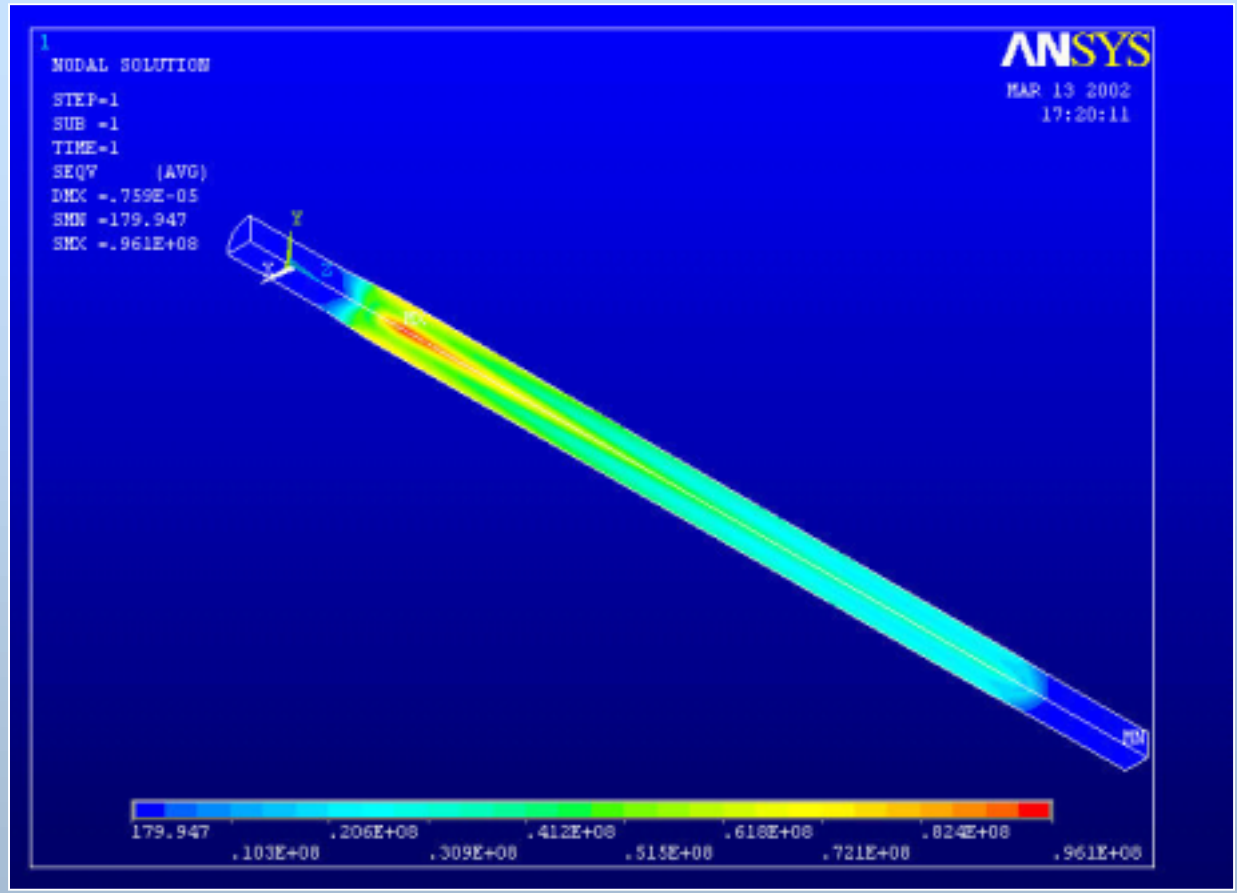
750 μm



Von Mises Stress

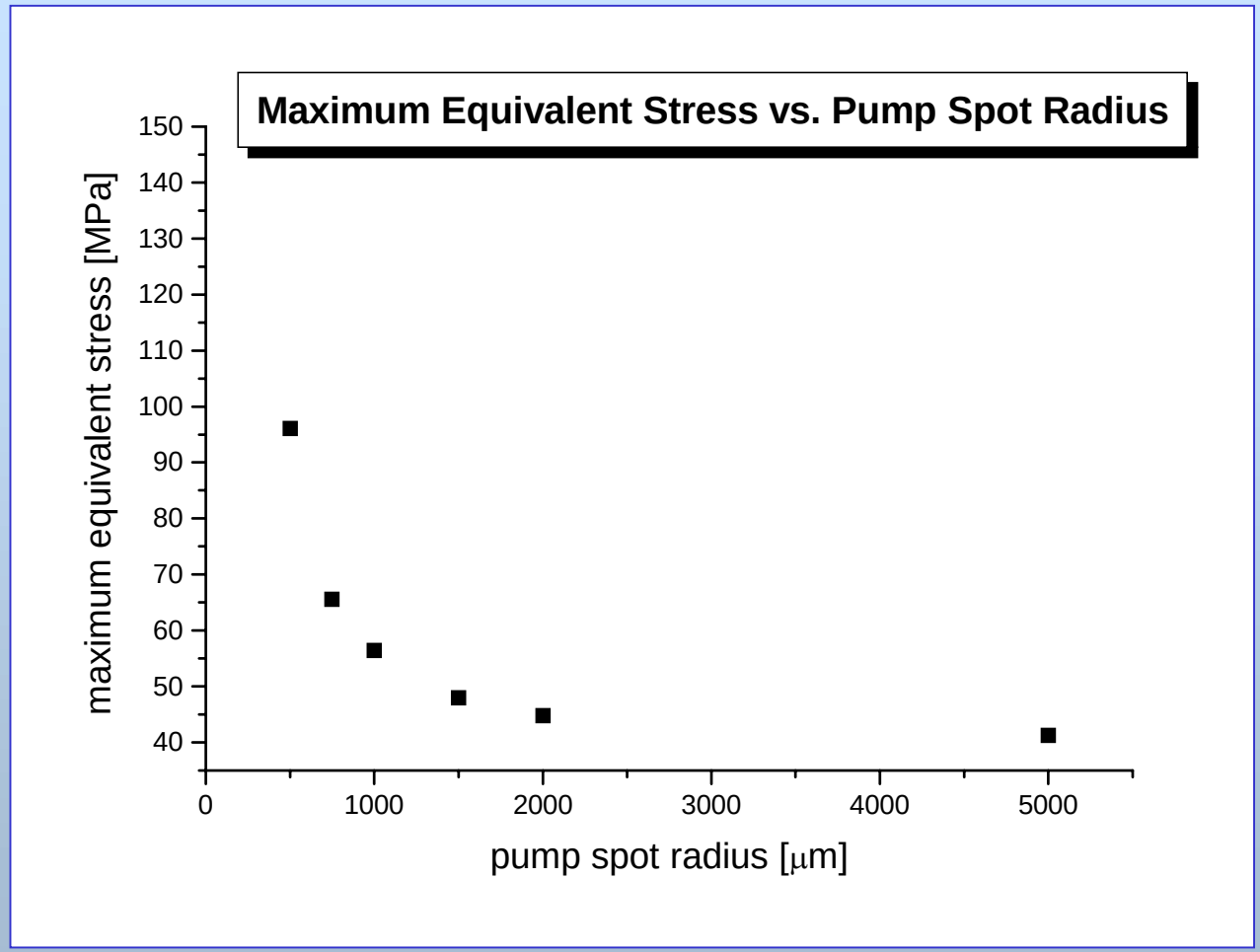
varying with pump spot diameter (pump power kept constant)

500 μm

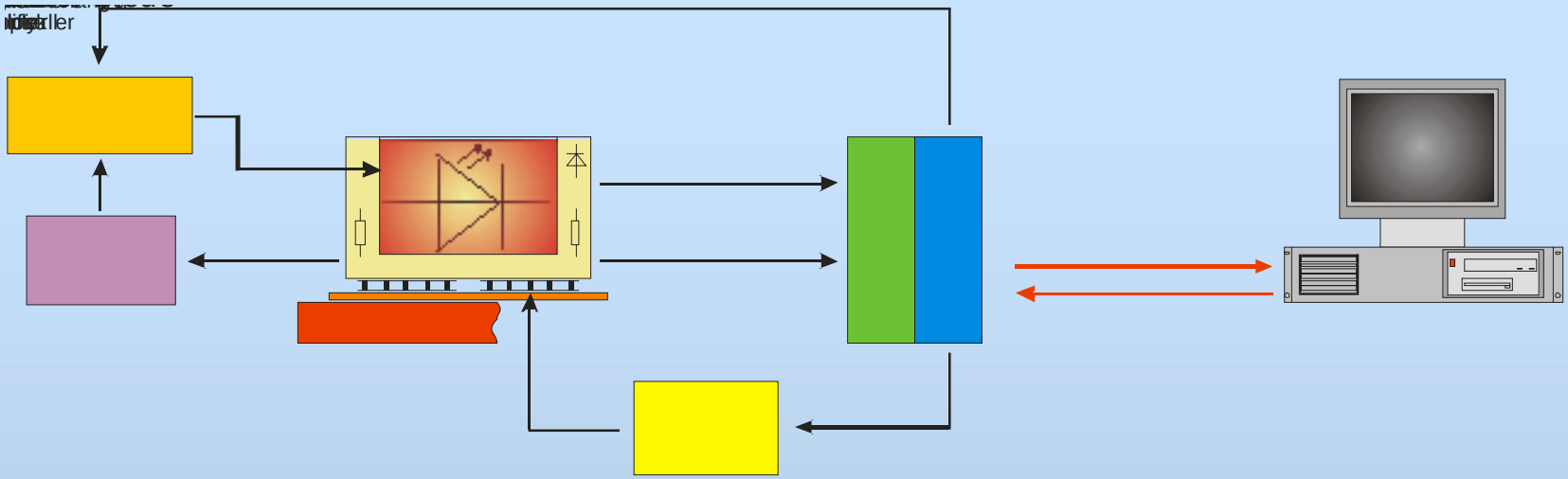


Mechanical Stress/Von Mises Equivalent Stress

varying with pump spot diameter (pump power kept constant)



Experimental/Diode Temperature Control



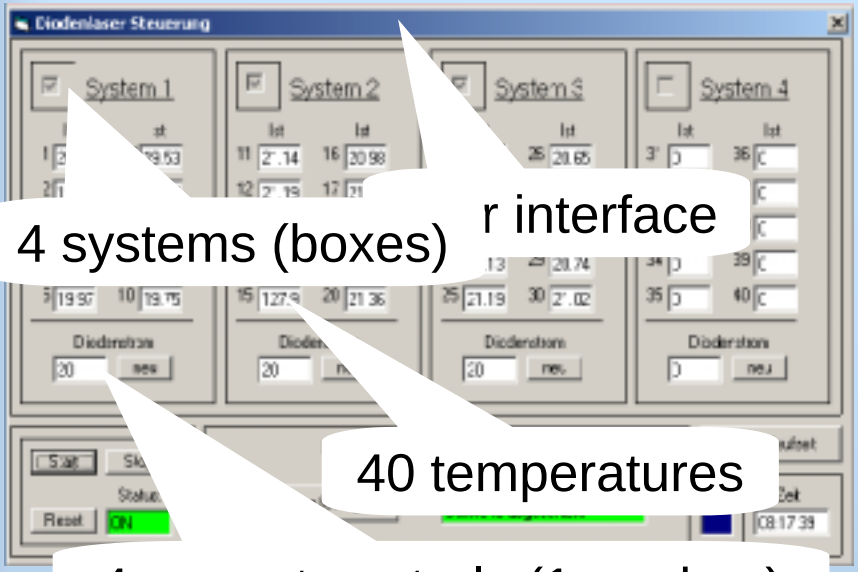
laser diode JENOPTIK 30 W, fiber coupled, NA 0.22; 800 µm

temperature resolution: 0.01K

temperature fluctuations: 2-3 digits

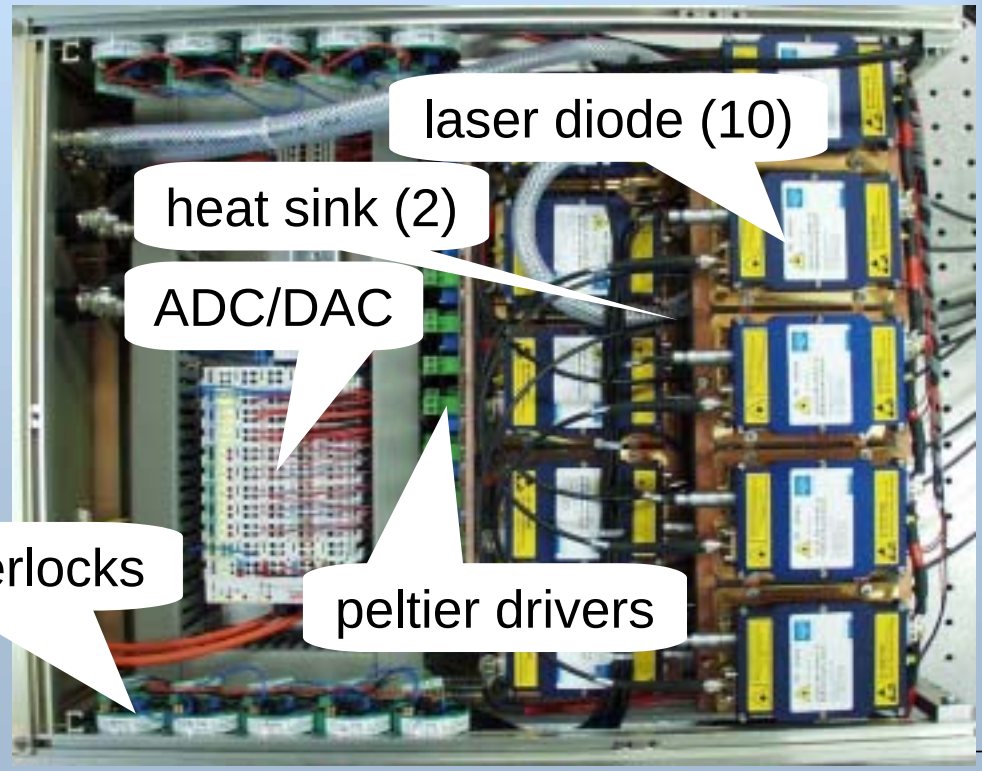
→temperature stability better than 0.05K

Experimental/Diode Box



- 4 boxes
- each 10 X 30 W fiber-coupled diodes

→ 1200 W pump Power

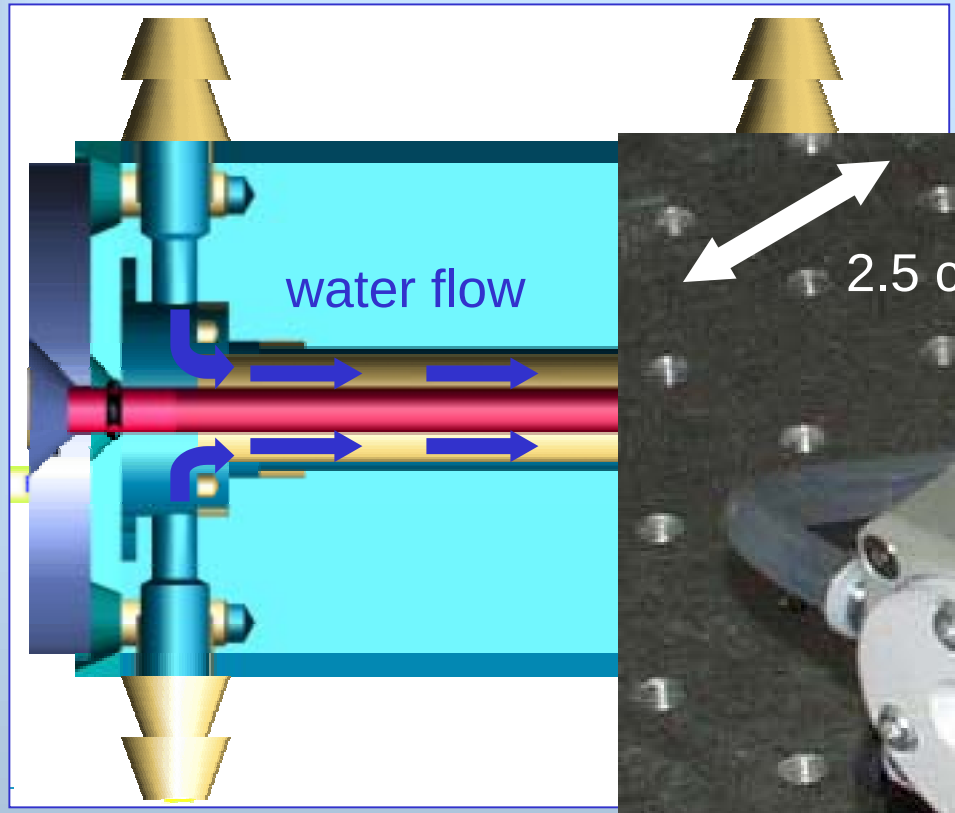


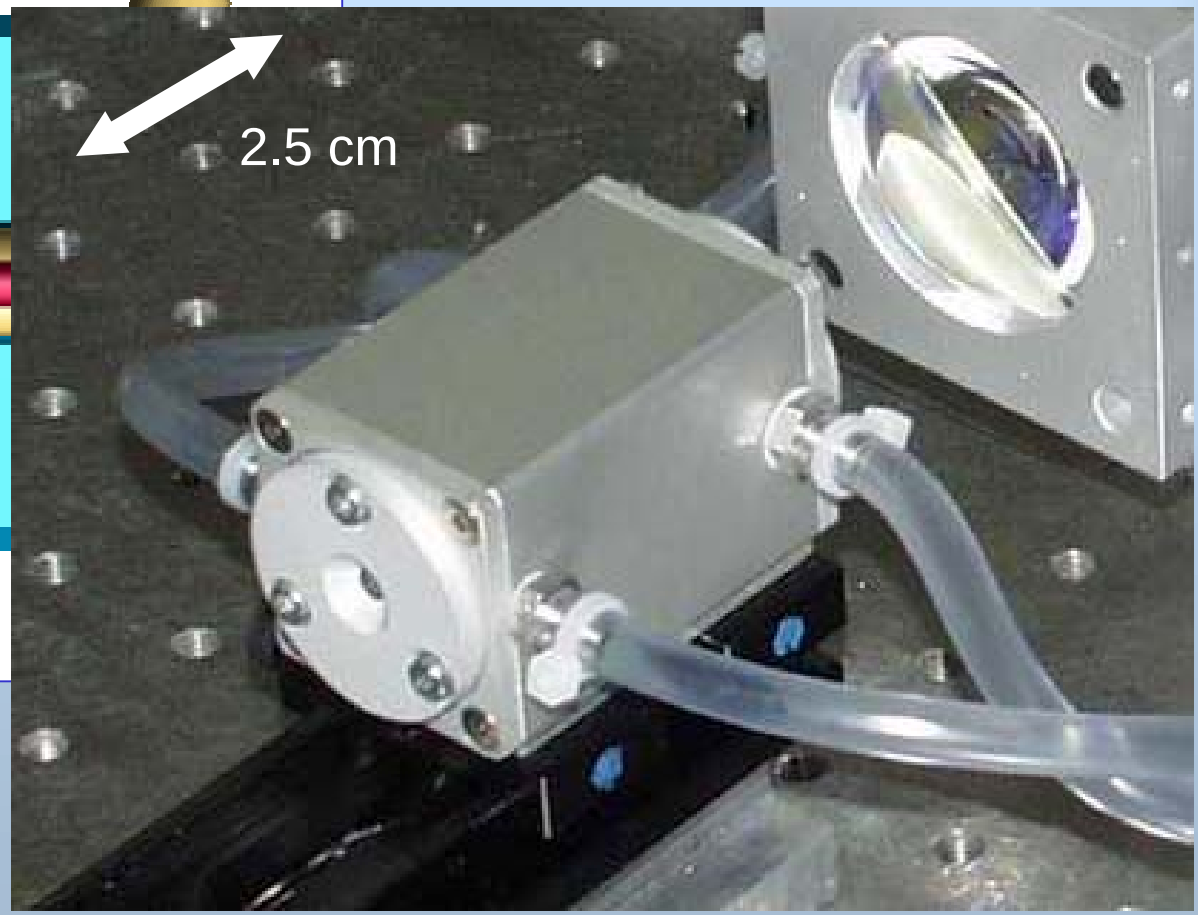
upcoming:

- 40 diode power measurements

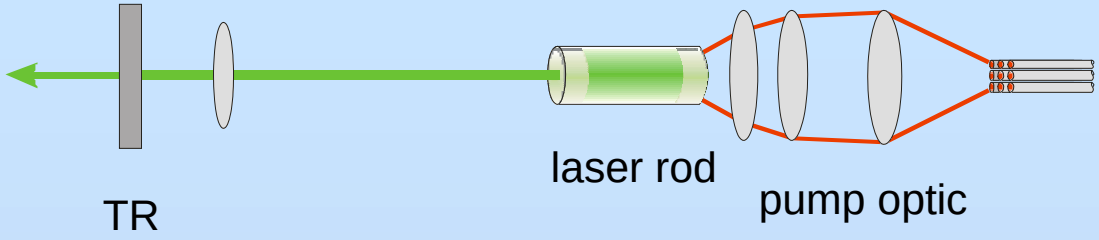
→ laser power control for each diode

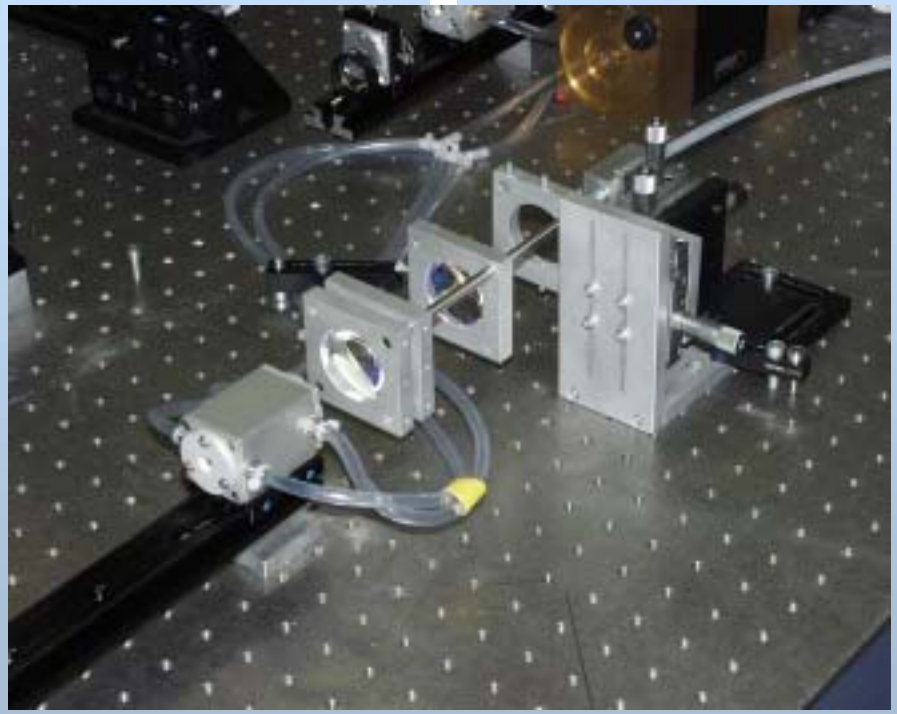
Pump Chamber

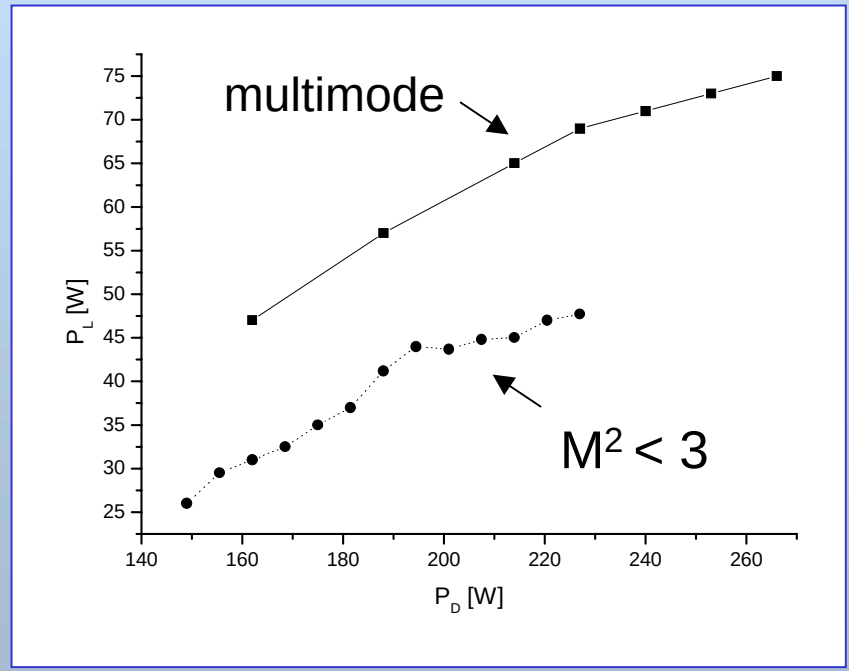




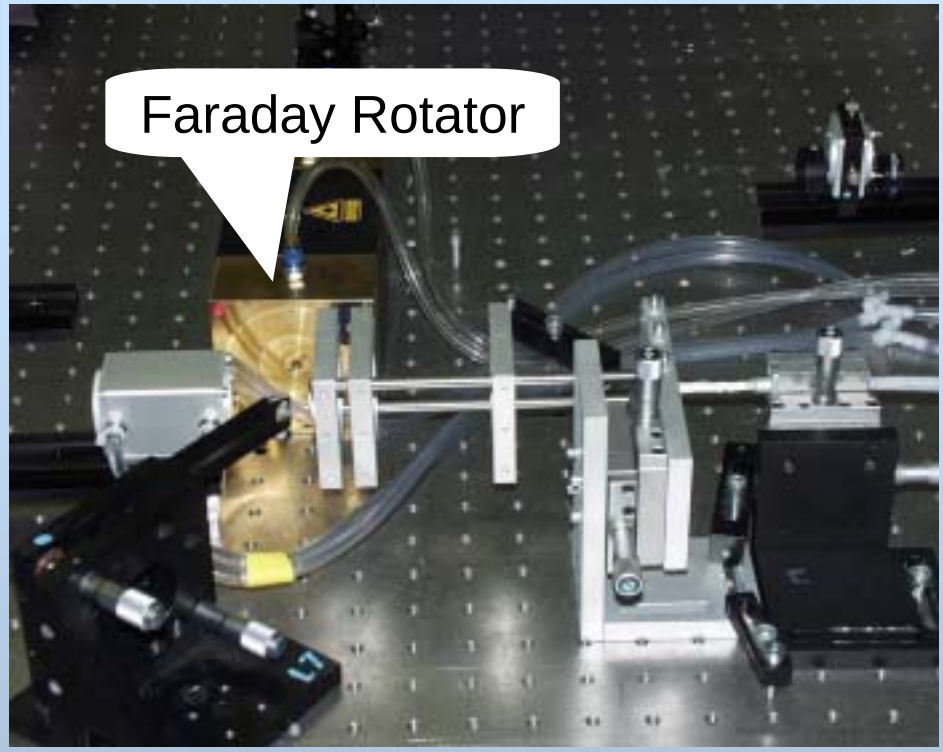
Pre-experiments

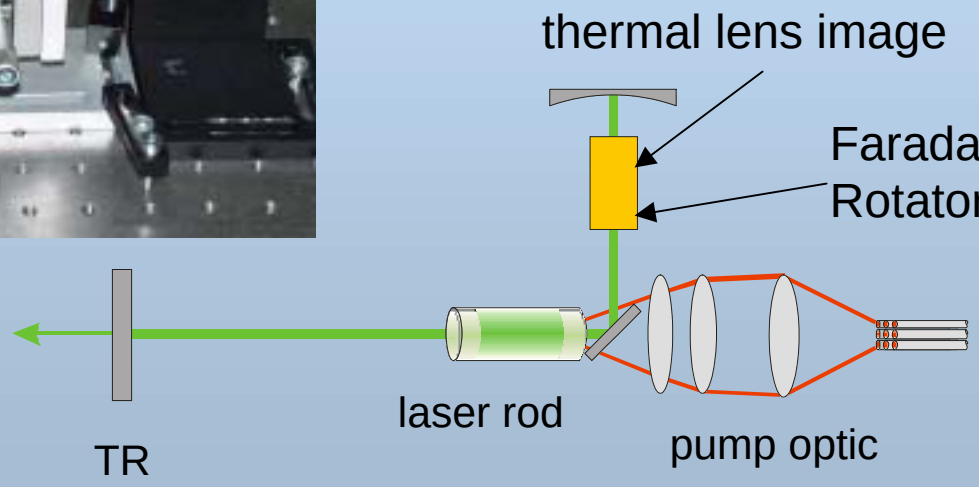






Birefringence Compensated Resonator





Resumé

- Modeling
  - 100 W of output power will be achieveable
  - abberations will have to be compensated for
  - abberations are comparable in end pumped and transversally pumped rod
- Experimental
  - 4 diode boxes have been set up (1200 W of pump power)
  - temperature stabilization works
  - pump light homogenization has been demonstrated
  - 45 W single mode and 75 W multi mode laser has been demonstrated (single rod, no compensation)

Outlook

- optimize overlap of pump light distribution and mode diameter
- compare calculated abberations to experiment (Shack-Hartmann sensor, diploma thesis P. Huke)
- evaluate conductive cooling (coating of rod‘s shell)
  - -reduce abberations (lower absolute temperature)
  - -avoid contact of cooling fluid with rod
- compensate for abberations