Optical gain in dye-doped polymer waveguides using oxidized porous silicon cladding

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Outline

- **Samples**
  - **Introduction to the used materials and sample preparation**
  - **Waveguide characterisation**
- **Losses and amplification measurements**
  - **Guided PL vs pump flux**
  - **Shifting Excitation Spot measurements(SES)**
  - **Variable Stripe Length measurements (VSL)**
- **Conclusions**

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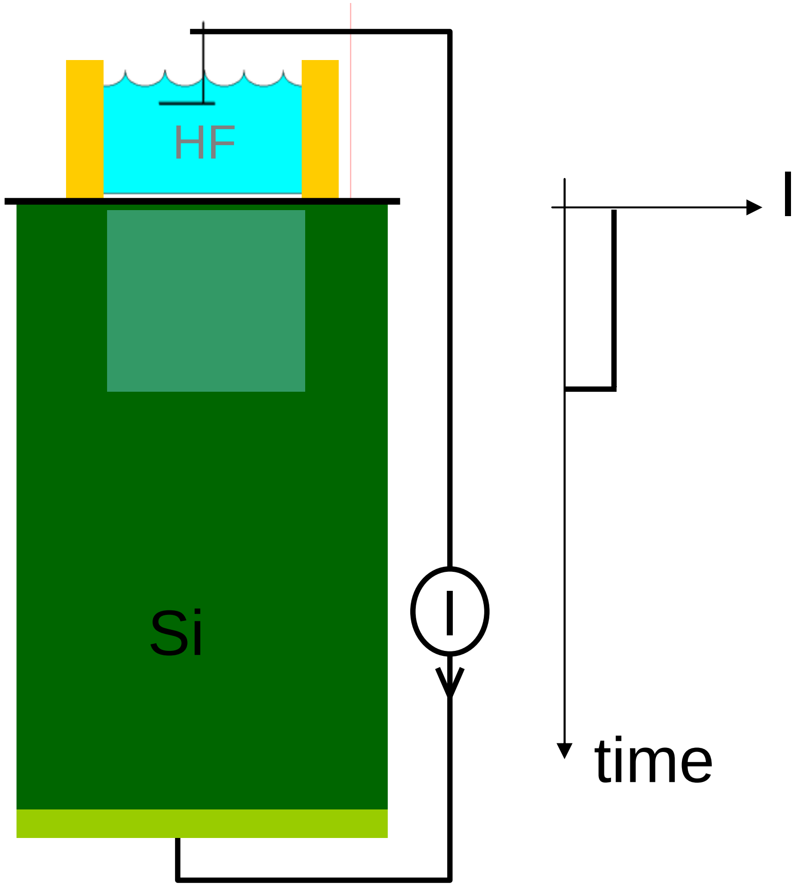
Samples

- Polymers: Offer cost-effectiveness, rapid processibility, low optical losses and low birefringence. Ideal plattform for the incorporation of more complex materials (laser dyes, nanodots, rare earth ions,..)

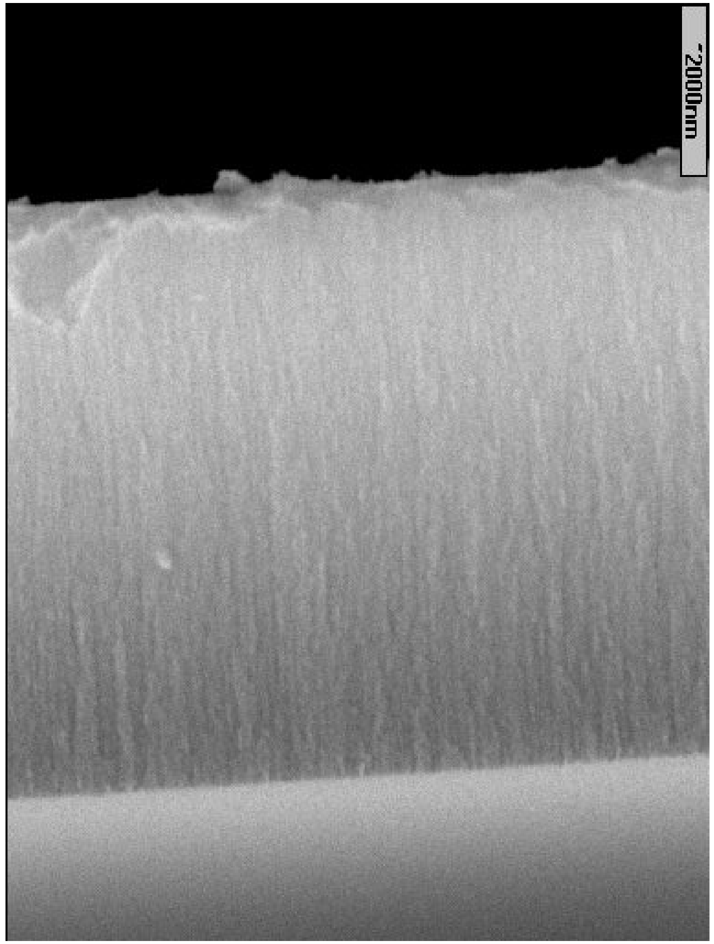
- Oxidised Porous Silicon: Good cladding material for building wavequides

Porous silicon formation

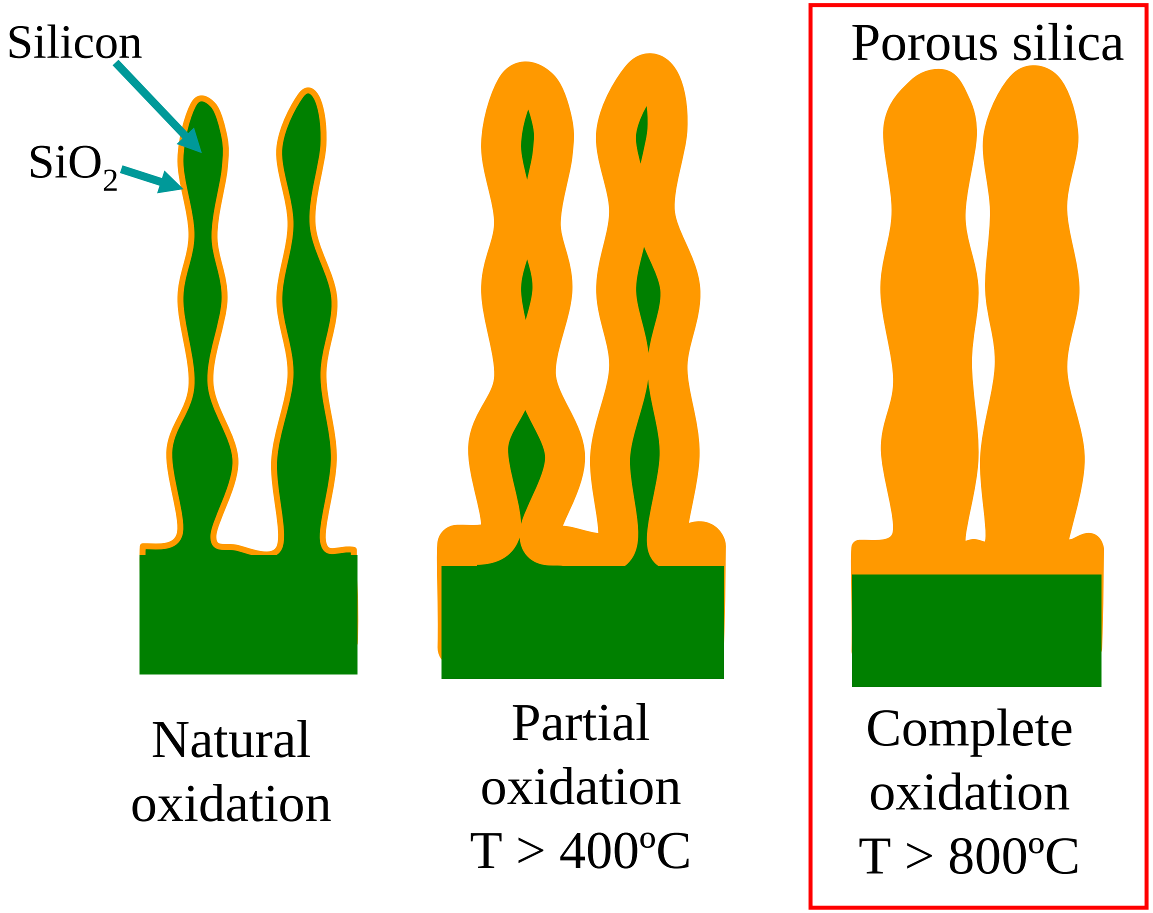


Pore dimension

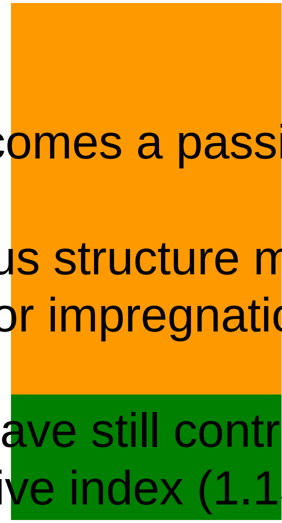
2 ... 50 nm



Effect of thermal oxidation



Consequences:

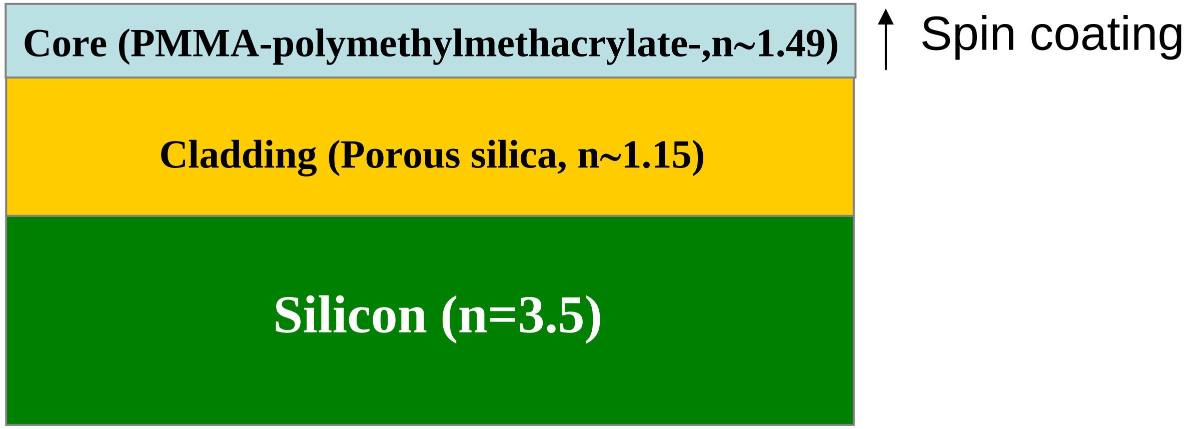


- It becomes transparent for the visible
- It becomes a passive material
- Porous structure maintained ⇒ good for impregnation
- We have still control of the refractive index (1.15<n<1.40)

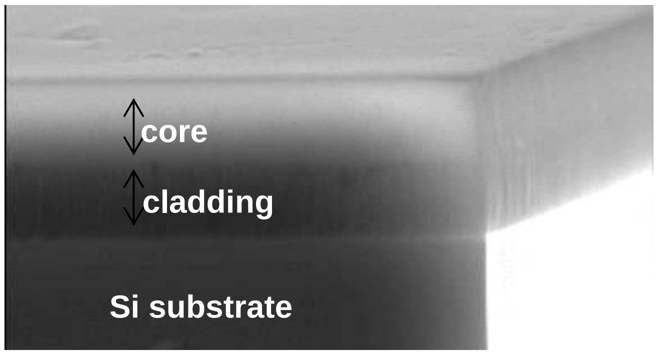
•Low refractive indices (n~1.15), close to air ⇒ good cladding material for building waveguides

Planar waveguides

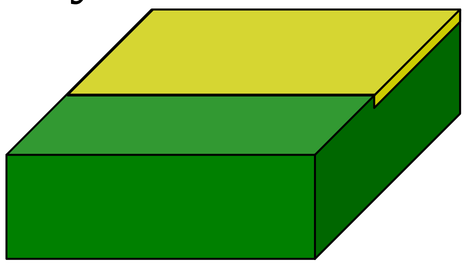
Polymeric waveguides with oxidized porous silicon cladding



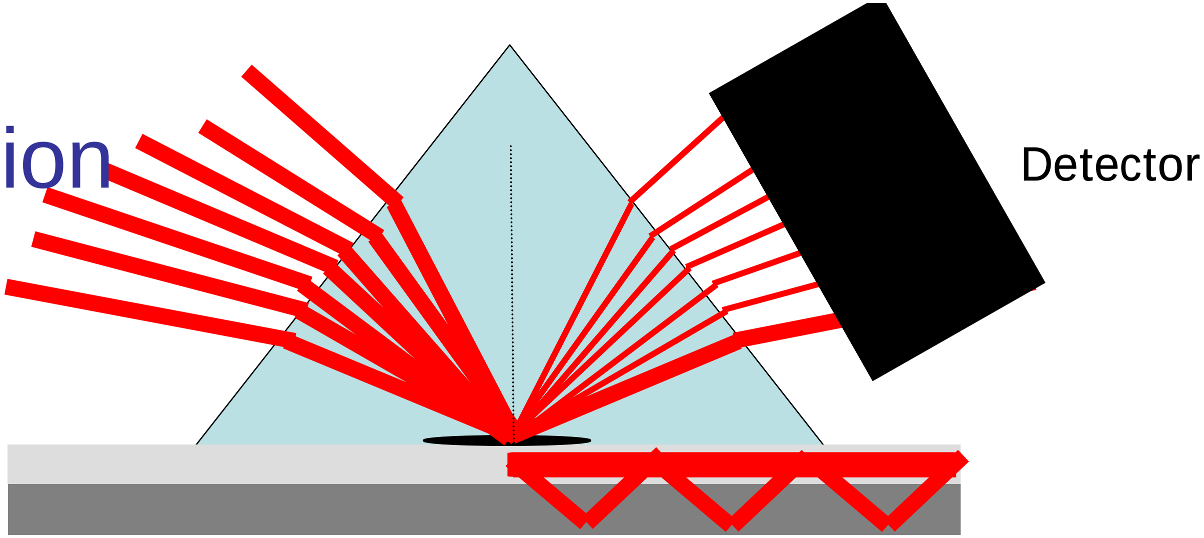
After oxidation (900ºC, 3h)



Cut this way:



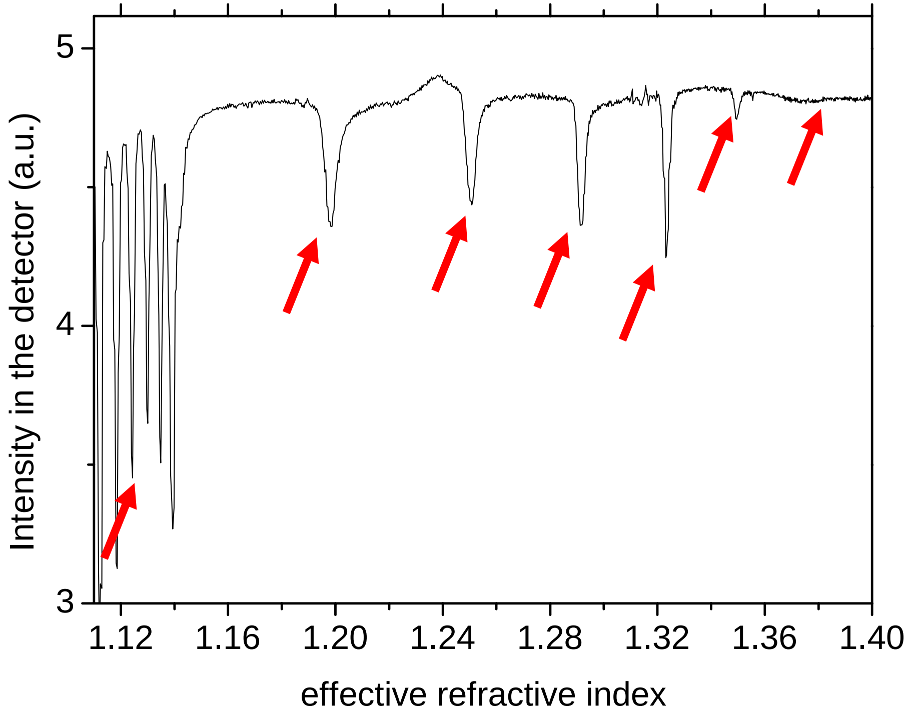
m-line characterisation



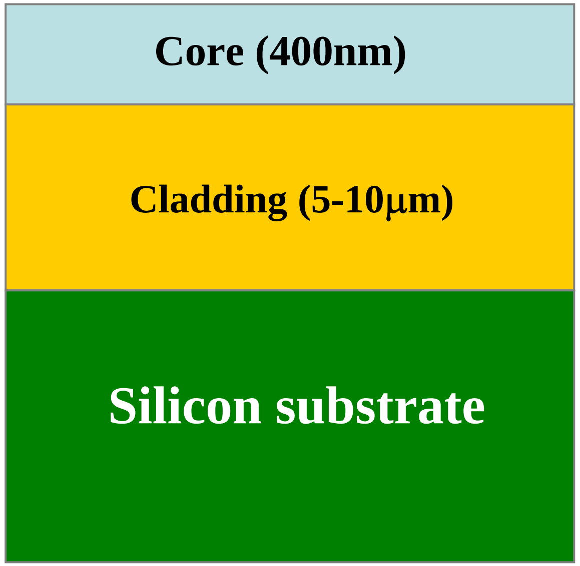
λ=633nm

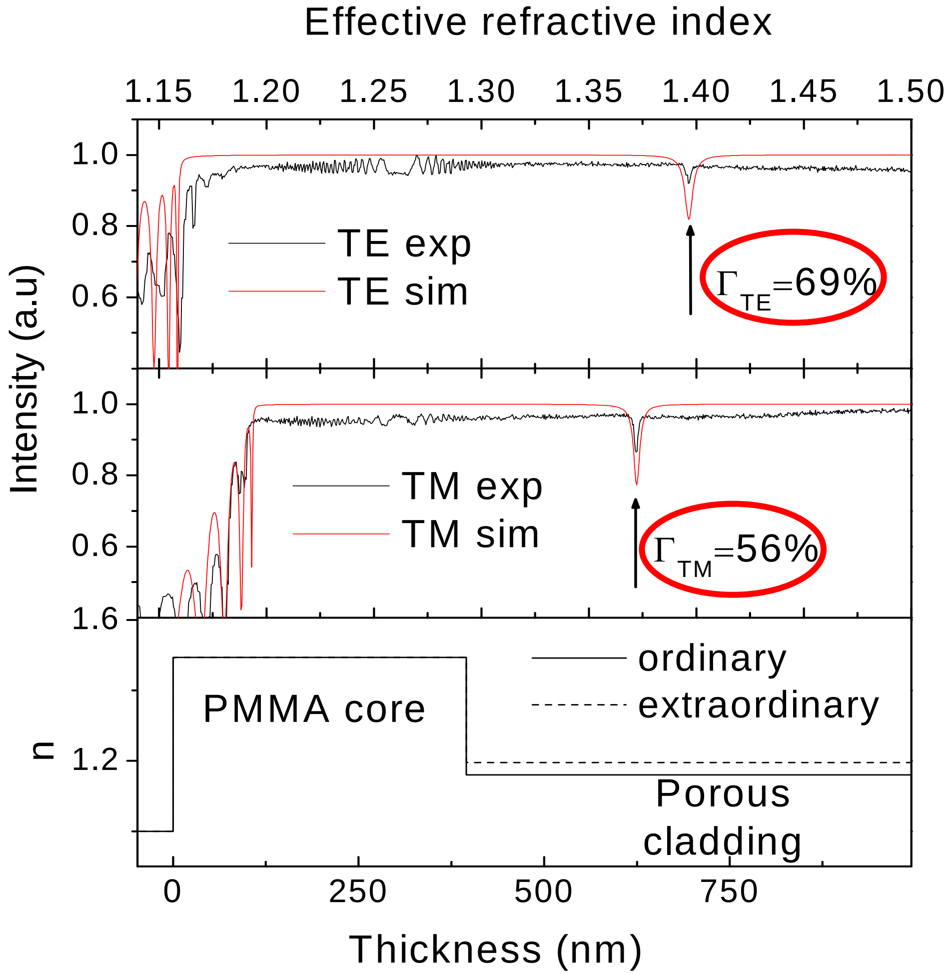
We can excite each of the modes supported by the planar waveguide

Knowledge of the effective refractive indices of the supported modes



Single-mode waveguides (λ=633nm)





If using a SiO_2 cladding, 1µm thick PMMA core should be grown for achieving the same confinement factors

High refractive index contrast ⇒ high compactness

Dye impregnation (Nile Blue-LC 6900)

Chosen because it is quite robust when dried.

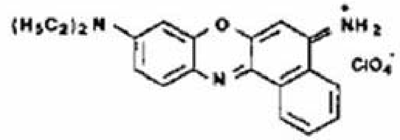
Impregnation:

Precursor PMMA solution mixed with the dye

No appreciable change in the waveguiding properties.

5-Amino-9-diethyliminobenzo[a]phenoxazonium Perchlorate

$C_{20}H_{20}N_3O_5Cl$ · MW: 417.85



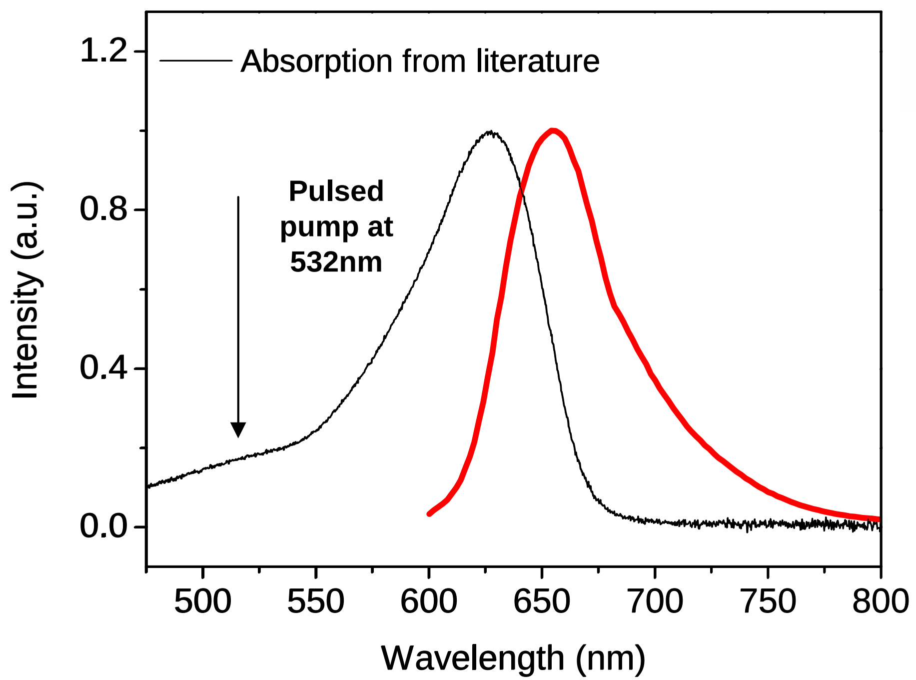
Characteristics

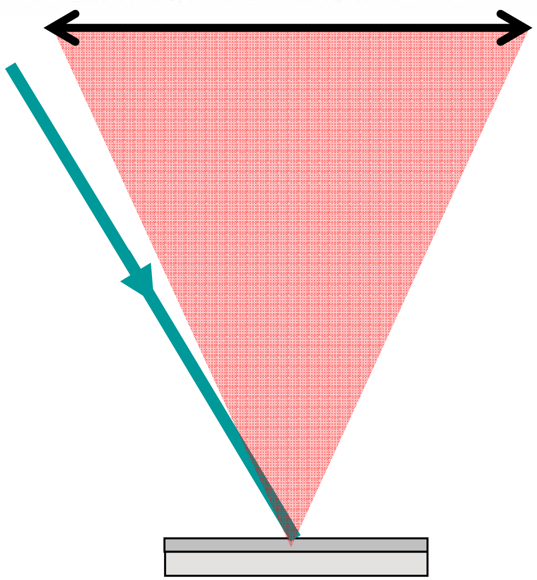
Lambdachrome® number:	6900
CAS registry number:	53340-16-2
Appearance:	green, crystalline solid
Absorption maximum (ethanol):	633 nm
Molar absorptivity:	7.75×10^4 L mol^{-1} cm^{-1}
Fluorescence maximum (in bas. ethanol):	672 nm

For research and development purposes only.

Lasing Performance

Laser dye for pulsed operation; tunable around 690 nm.





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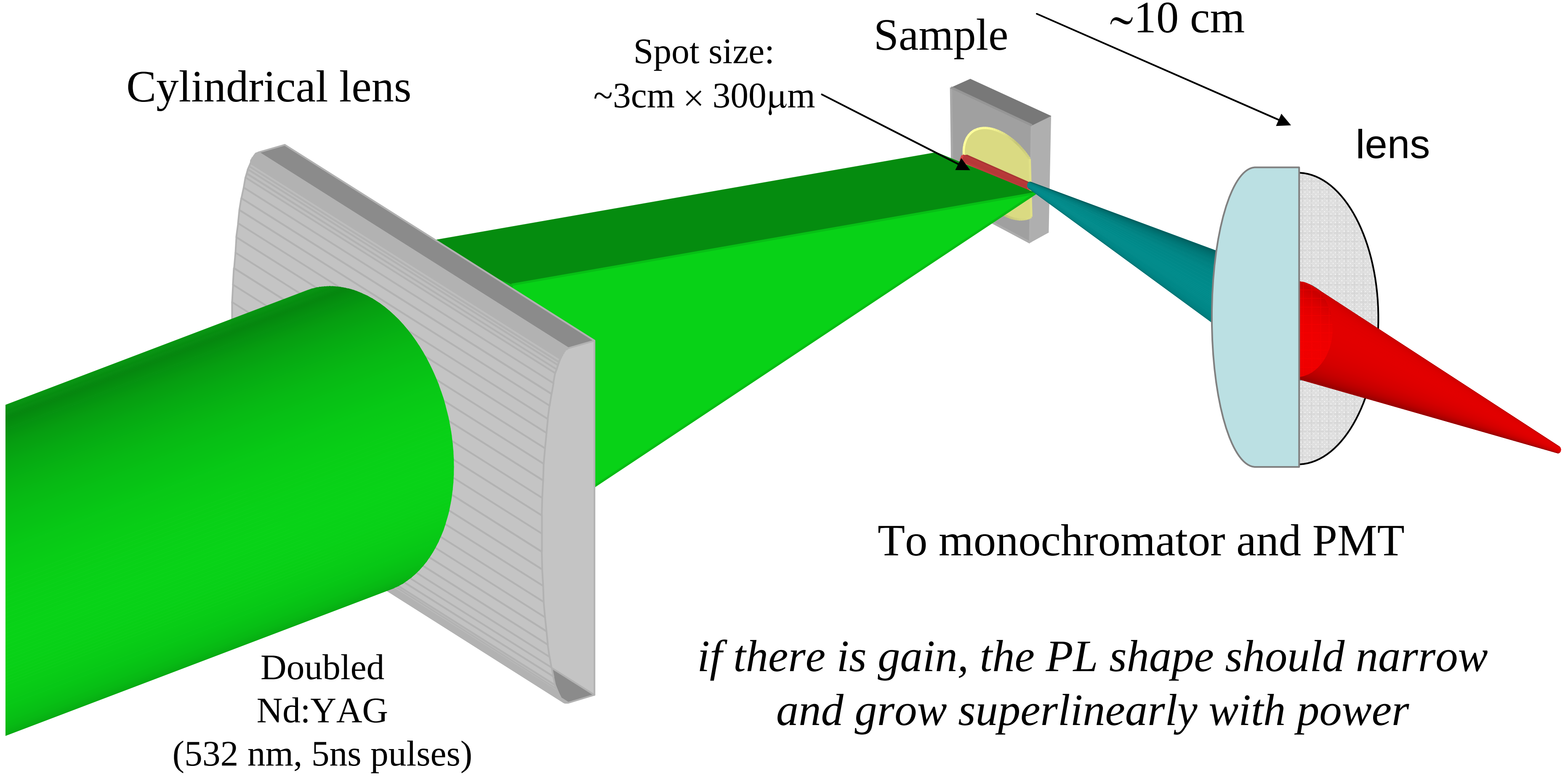
Experimental setup

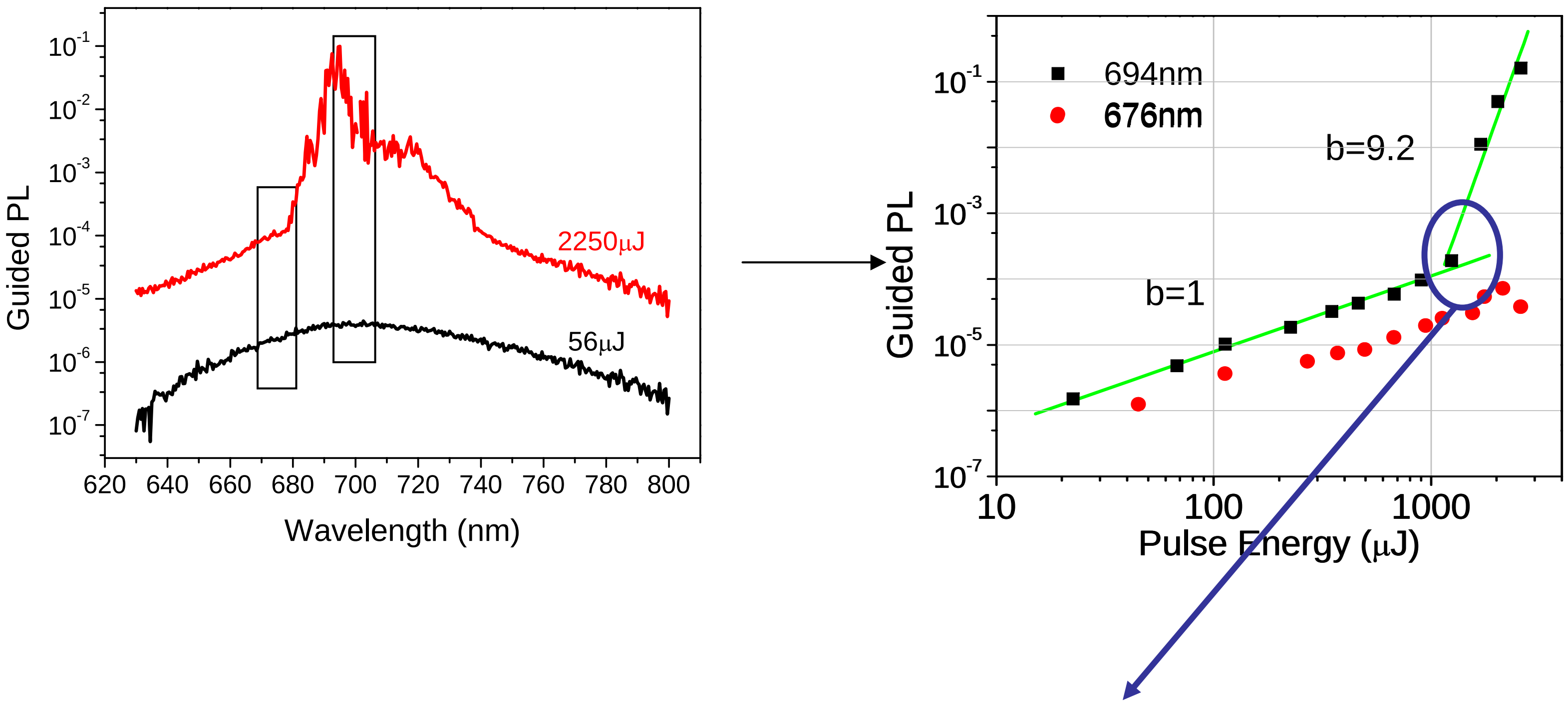
Guided PL setup



if there is gain, the PL shape should narrow and grow superlinearly with power

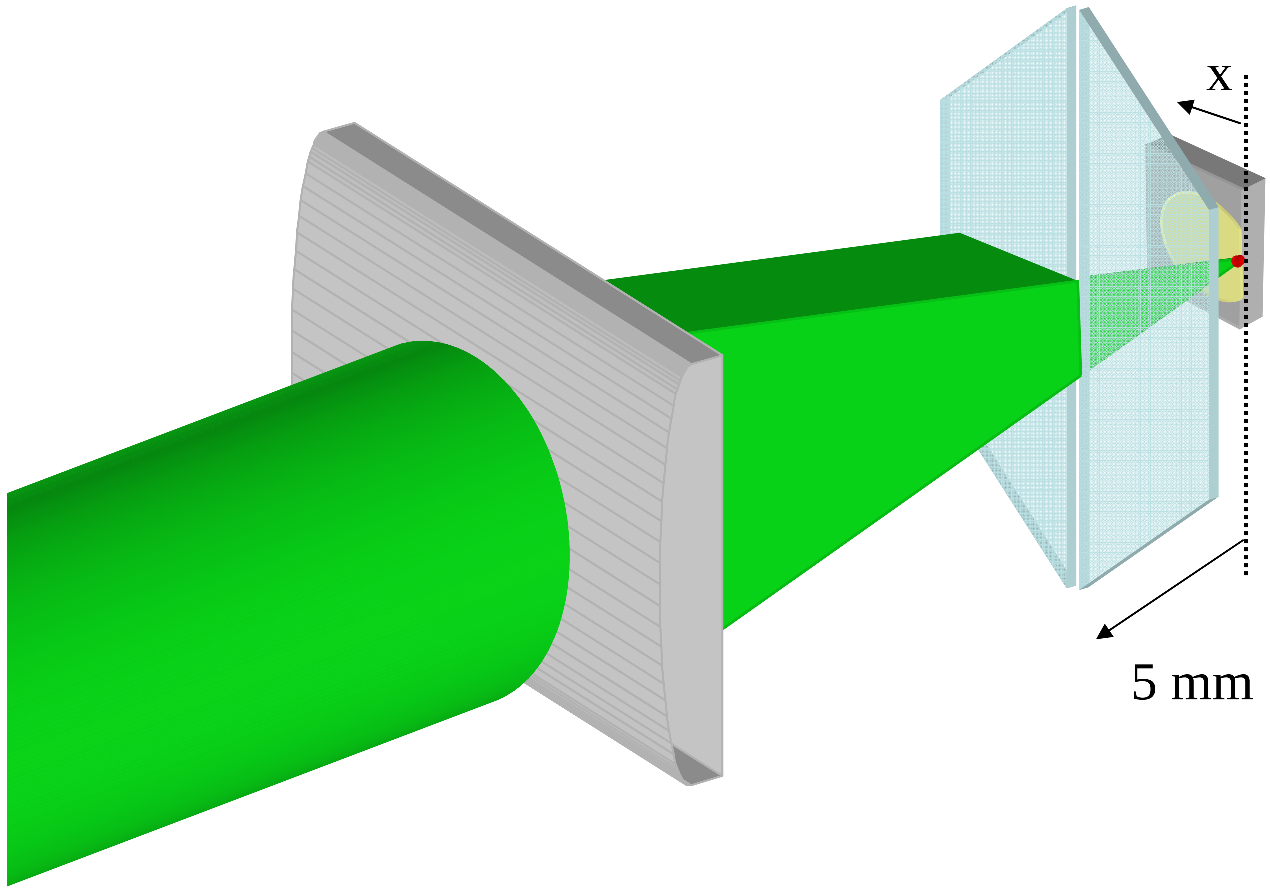
Guided PL vs Pump Power

$$I = a\phi^b$$



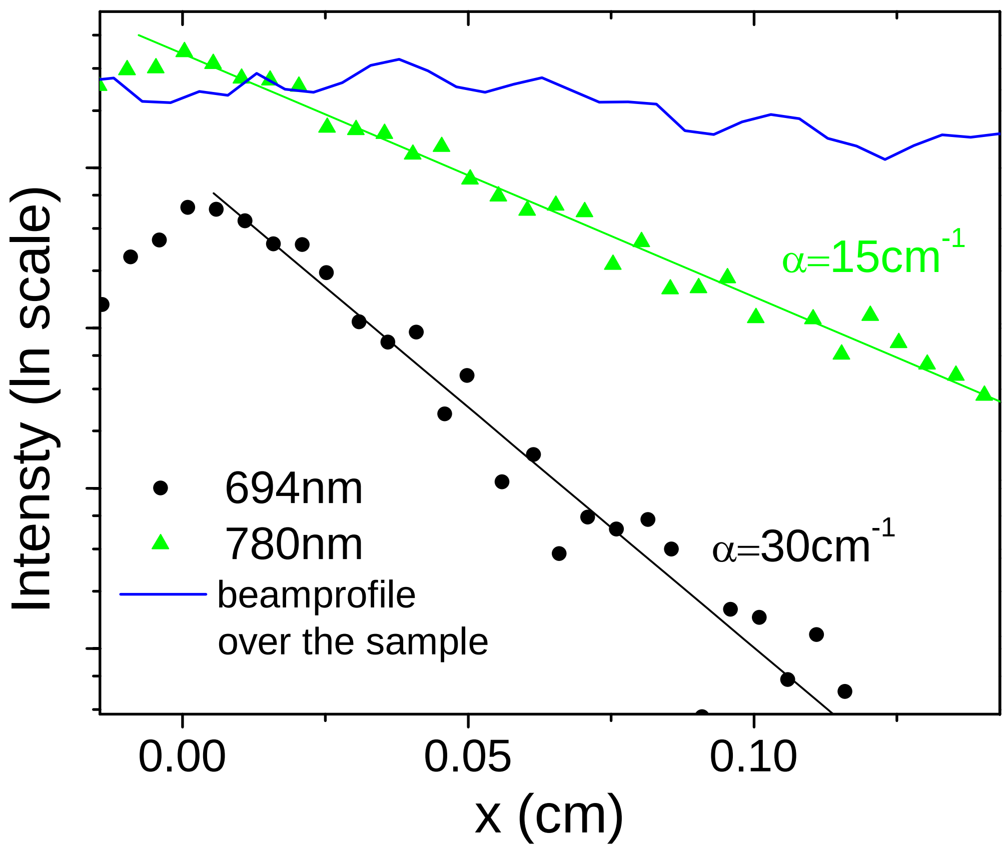
Threshold found at 1.5mJ

Shifting excitation spot (SES)



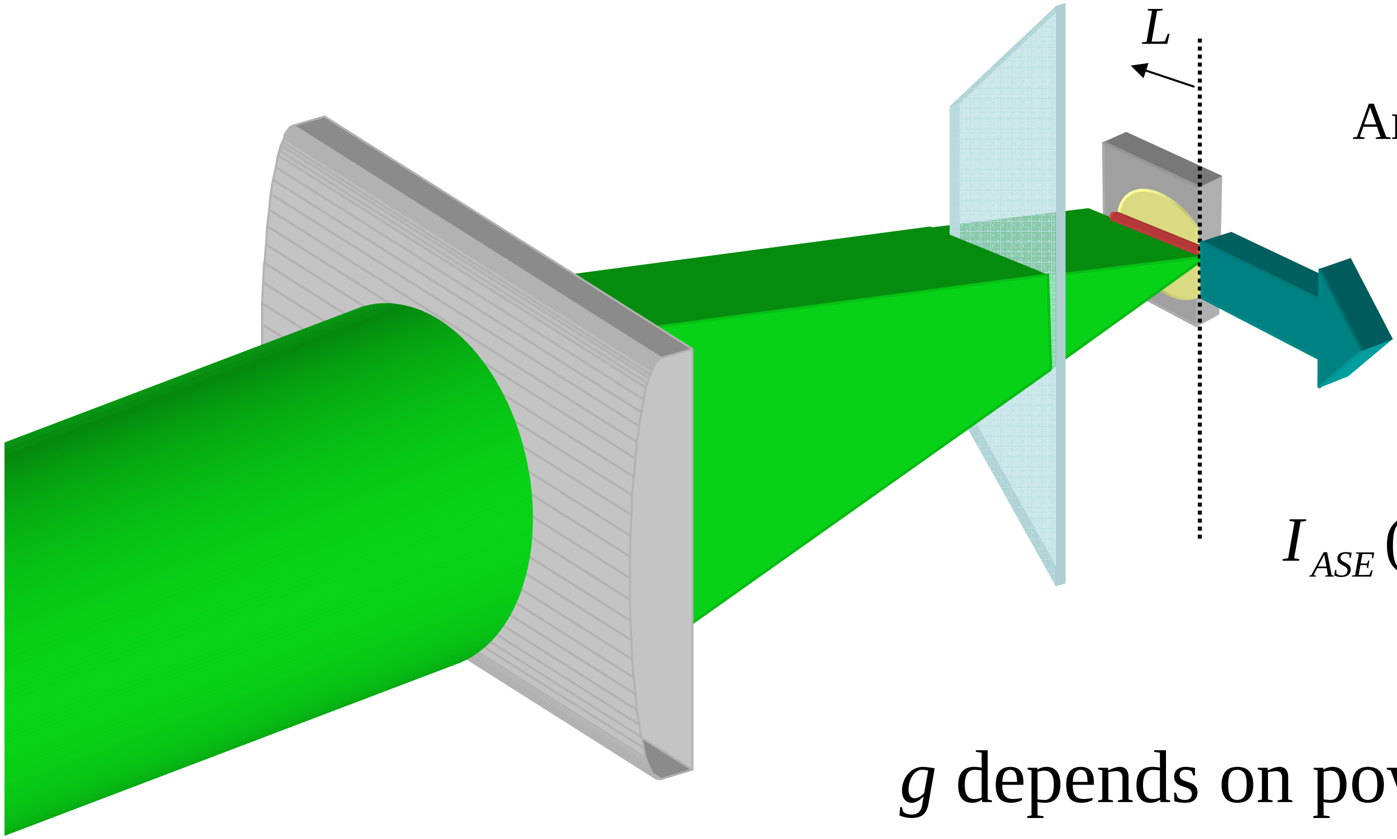
$$I_{SES}(x) = I_0 \exp(-\alpha x)$$

SES results



Intensty (ln scale)
α=15cm-1
694nm
780nm
beamprofile
over the sample
α=30cm-1
0.00
0.05
0.10
x (cm)

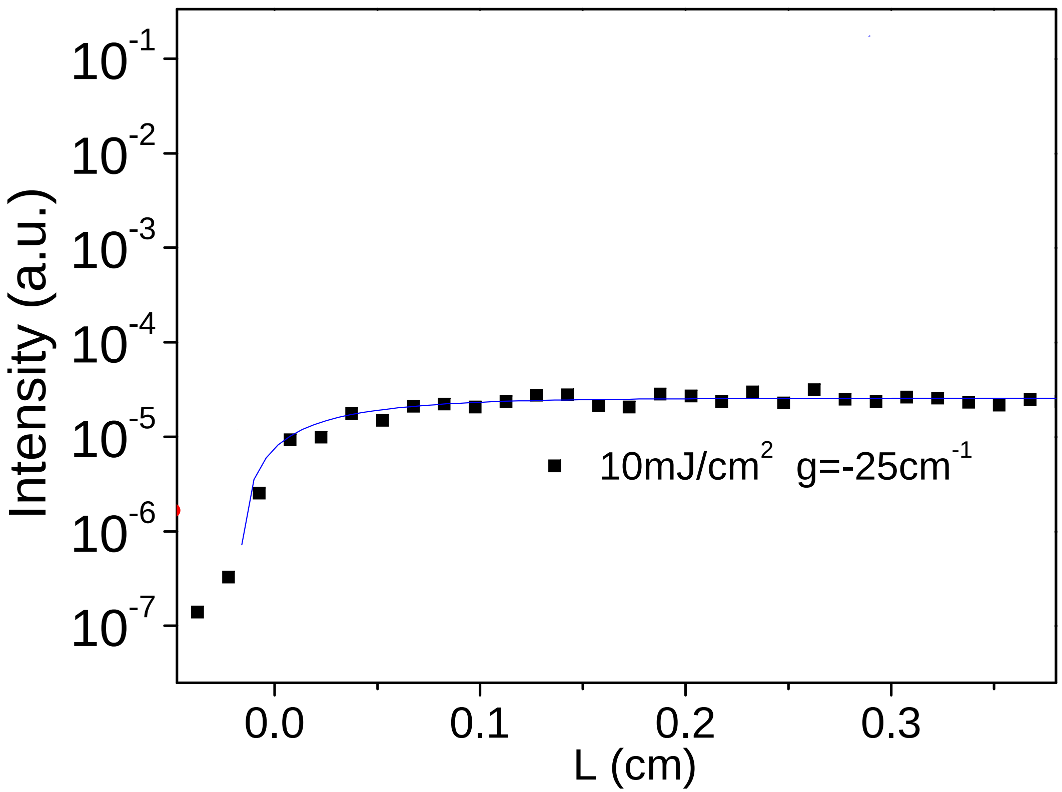
Variable Stripe Length (VSL)



$$I_{ASE}(L) \propto \frac{1}{g}\exp(gL-1)$$

g depends on power!
And passes from negative to positive values by increasing the pump flux

VSL results (λ=694nm)



Low pump power:

•Losses of **-25 cm^{-1}** have been observed.

•The value is compatible to what measured with SES.

High pump power:

•Net optical gain of **24 cm^{-1}** has been observed.

•Constant over 3mm $\Rightarrow$ Absolute gain of **31dB** at 694nm

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- We have built **highly compact** slab optical waveguides using a new **hybrid approach** (cladding layer of extremely low refractive index porous silica + core layer of PMMA doped with a laser dye).

- We have demonstrated the feasibility of using oxidised porous silicon as a **cladding material** for growing compact optical amplifiers

- We have measured **evidences of optical gain**:
  - Dramatic line narrowing
  - Superlinear guided PL increase with power
  - VSL goes from sublinear to exponential increase
  - Low power VSL compatible with SES

- We have measured gain values up to **24 cm^{-1}** $\Rightarrow$ **31 dB** at 694nm

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THANK YOU!