TEM_{00} fiber laser emitting 94W at 977 nm

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Outline

1. Introduction
2. Experimental setup
3. Results and simulations
4. Applications

Needs for high brightness sources emitting at 976 nm

- ✓ Optical pumping of Yb or Er doped material:
  - Laser diodes : few W
  - VECSEL : mW
  - Yb-doped lasers : 1.4 W
- ✓ Blue sources at 488 nm for biology or telecom:
  - Argon lasers
  - Frequency doubled sources at 976 nm

↓

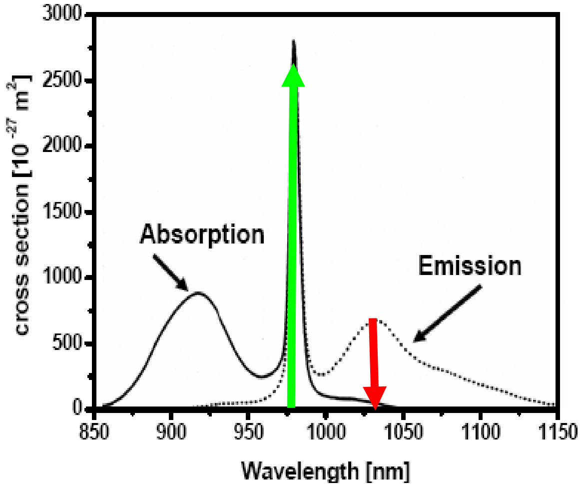
No available sources in excess of 10 W

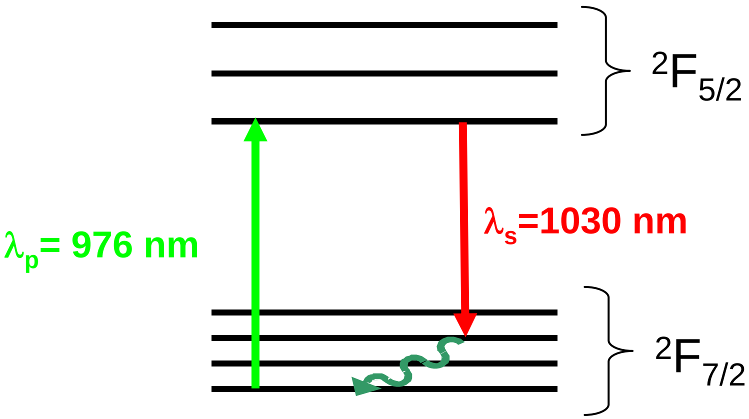
➡ **Yb-doped double clad fiber laser solutions for 100 W class sources**

Laser operation

Configuration ①

Yb-doped fiber

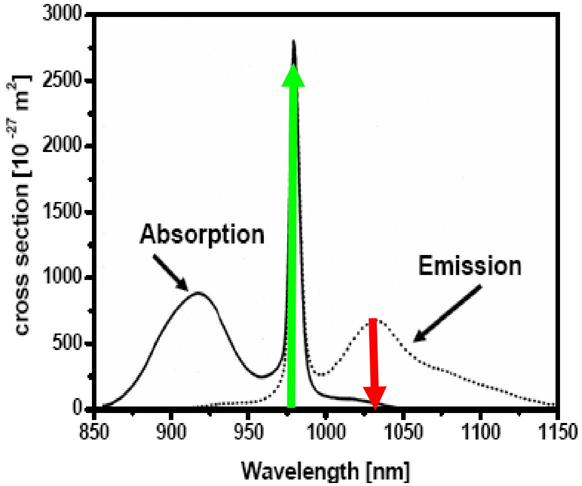


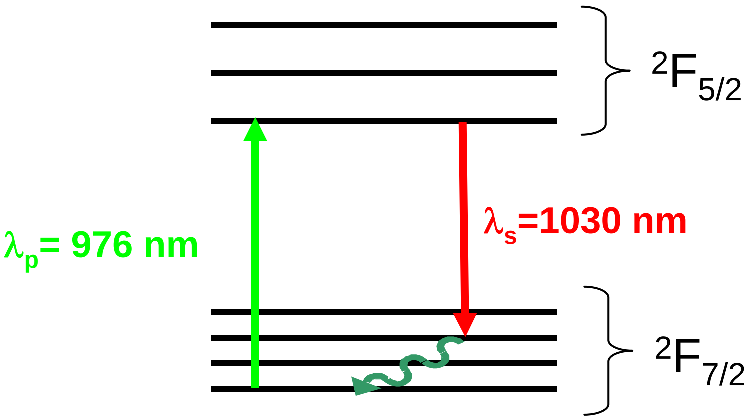


Laser operation

Configuration 1

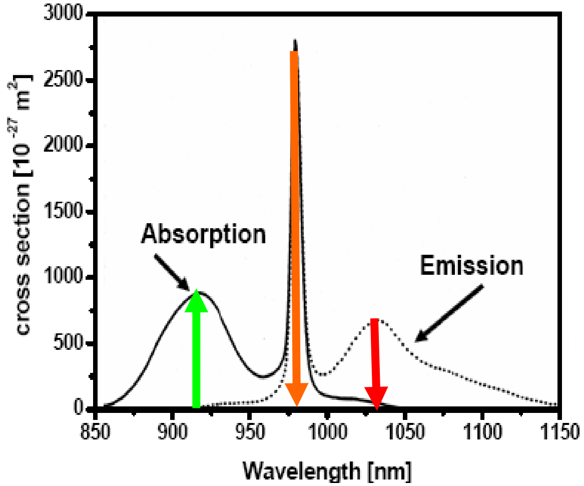
Yb-doped fiber

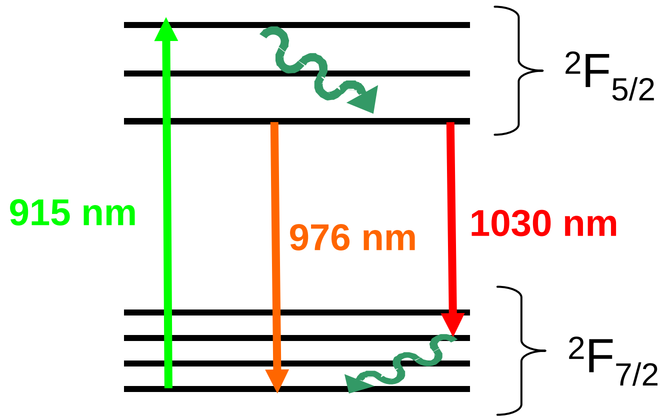




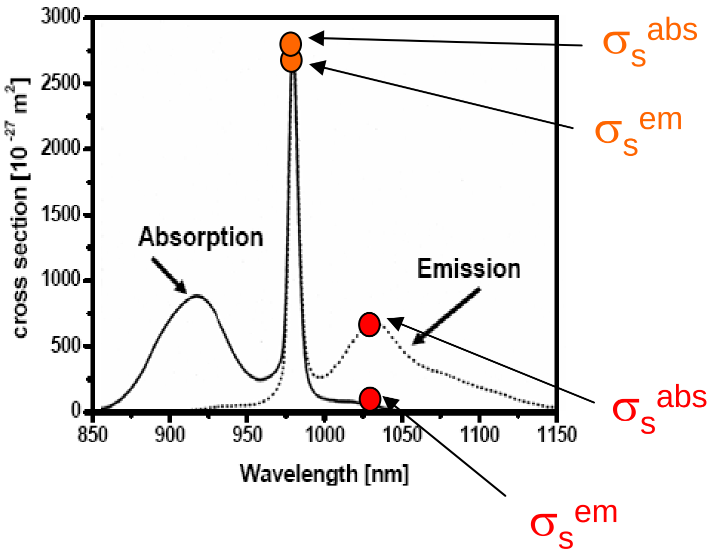
Configuration 2

Yb-doped fiber





Main issues



① Transparency:

$$\sigma_s^{em} \sim \sigma_s^{abs}$$

Bleaching is achieved if :

$$\frac{n_2^{trans}}{n_{Tot}} = \frac{\sigma_s^{abs}}{\sigma_s^{abs} + \sigma_s^{em}} \approx 50\%$$

for a pump intensity of:

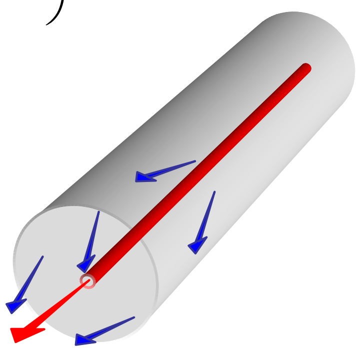
$$I_p^{trans} = \frac{h\nu_p}{\left(\frac{\sigma_p^{abs}\sigma_s^{em}}{\sigma_s^{abs}} - \sigma_p^{em}\right)\tau_{fluo}} \approx 30 \text{ kW/cm}^2$$

② Gain competition and induced losses:

$$G_{1030} = 0.25\, G_{976} + 0.72\alpha_p \beta$$

Pump absorption (α_p)

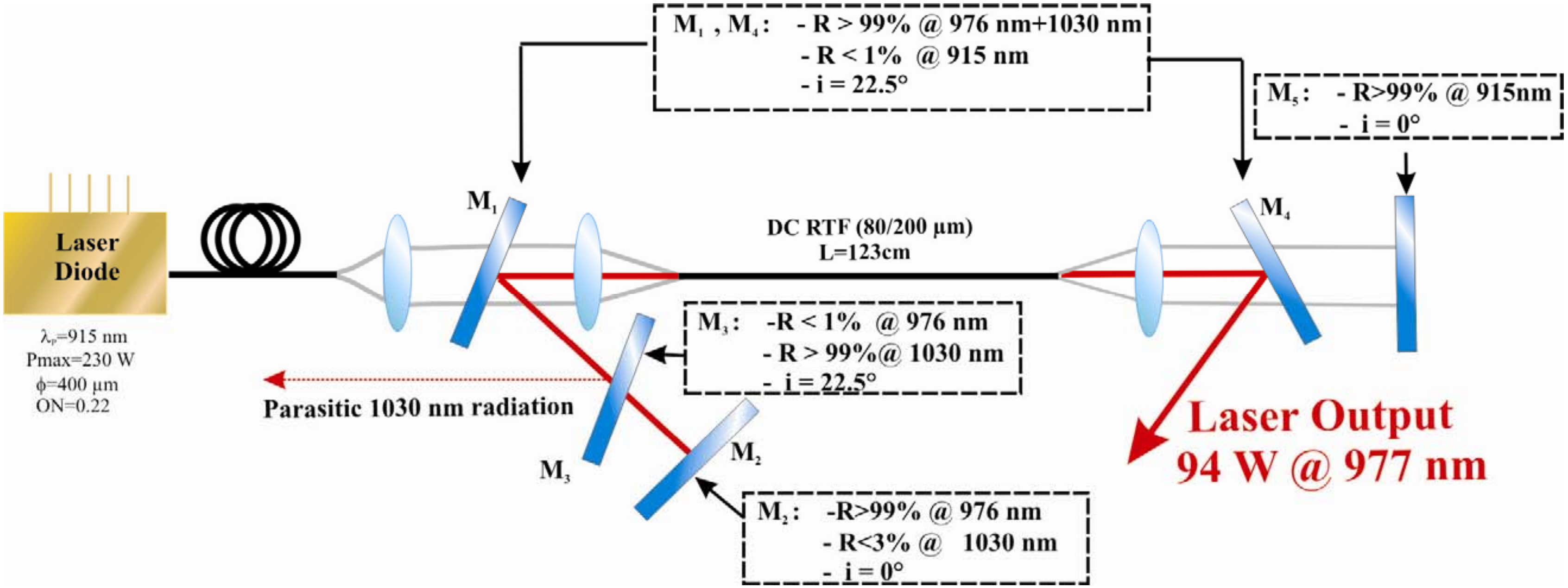
Clad to core area ratio (β)



Large β will lead to negligible gain at 976 compare to 1030

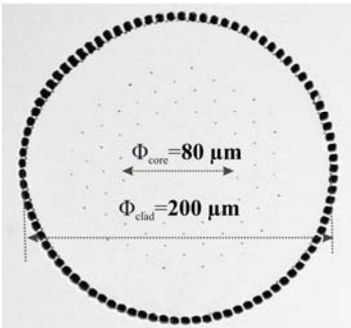
➡ **Invert 50 % of the population**
Achieve small β value
Induce losses > G_{1030}

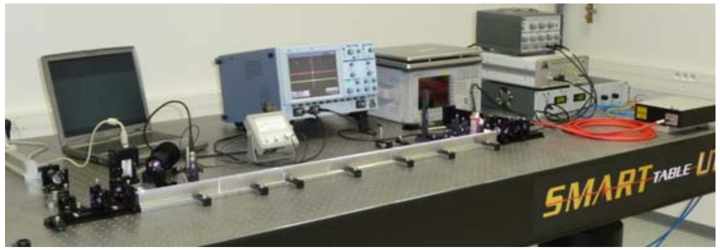
Experimental setup



Rod type fiber :

Microstructured
Double clad Yb doped
80µm/200µm
Absorption: 10 dB/m
Length : 1.2 m





① P_{trans} = 11 W
② β = 6.2, losses = 60 dB

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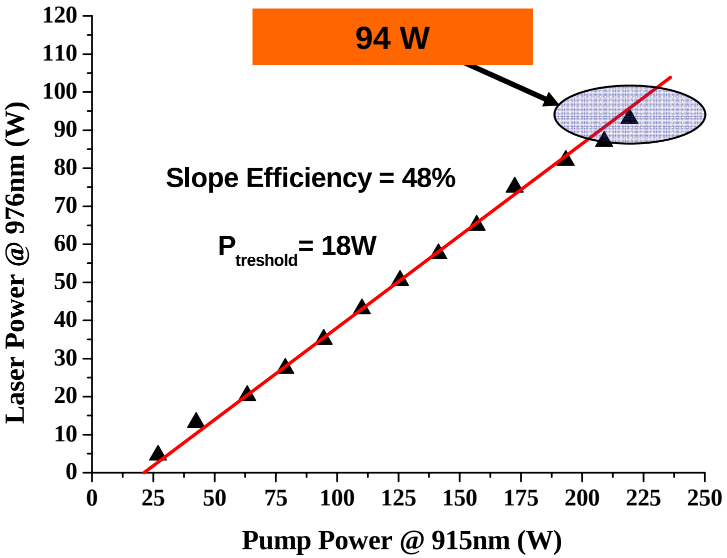
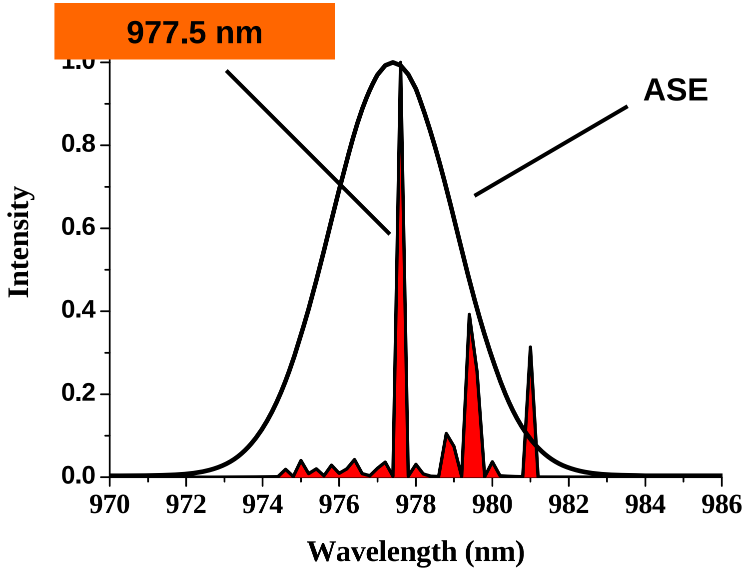
Results

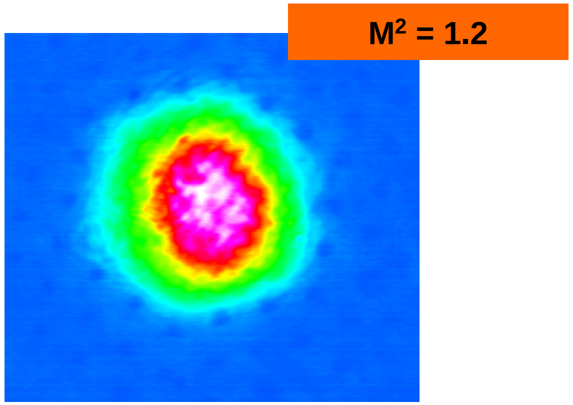
Efficiency :



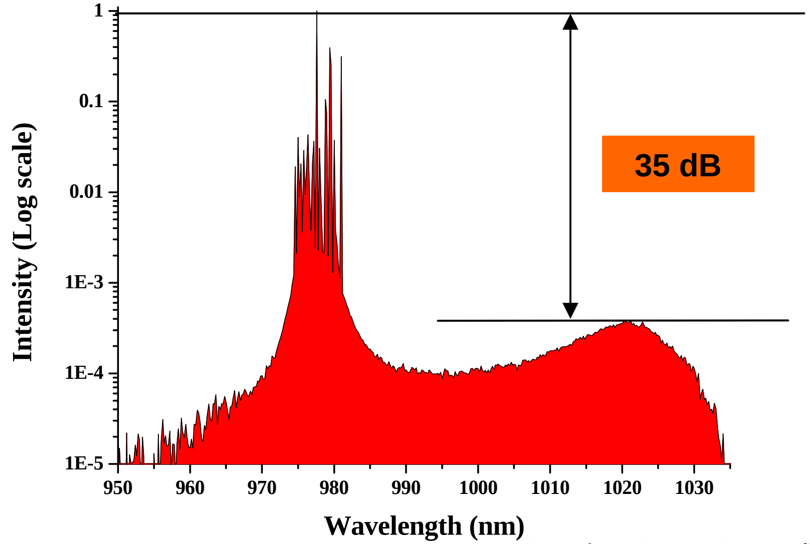
Spectrum :



Beam quality :

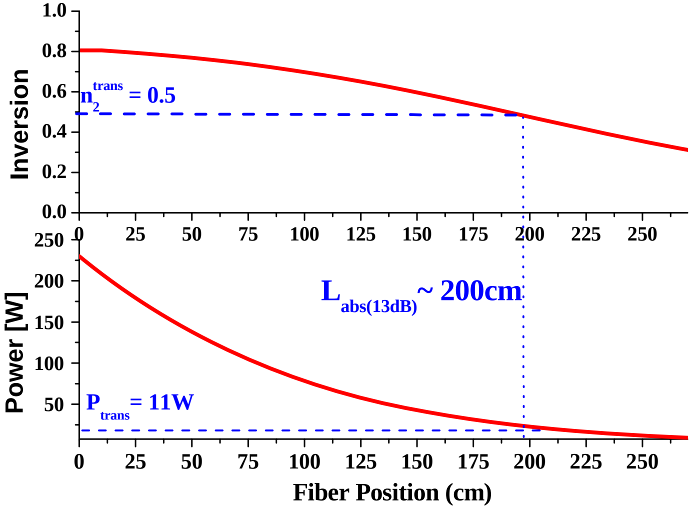


Parasitic lasing suppression :

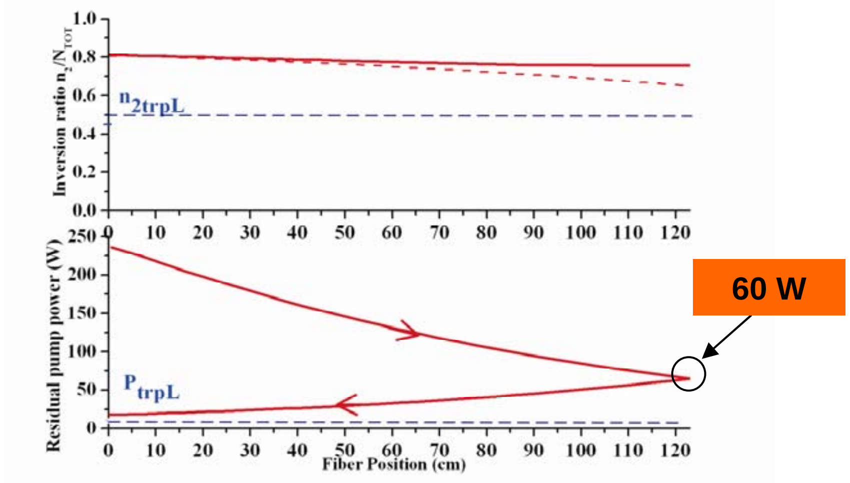


Simulations

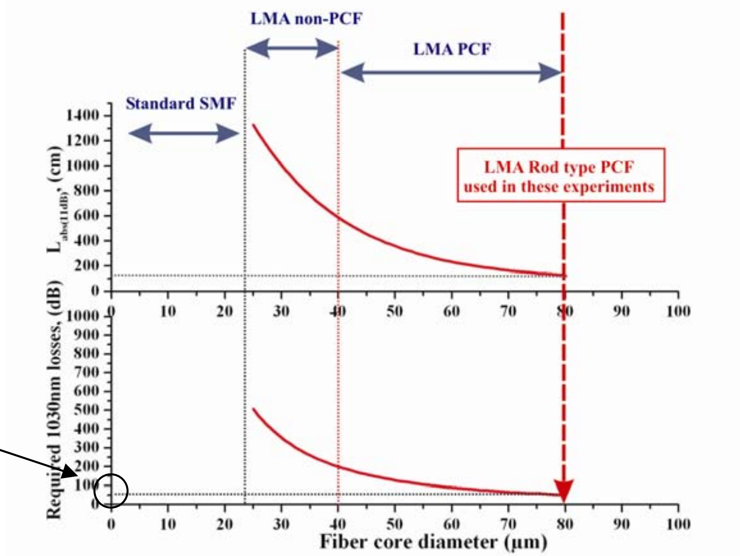
Population inversion:



Pump reinjection:



Losses at 1030 nm:



Our experiment:

Cavity losses : 14 dB

Medium gain : G_{976} = 7 dB per pass

Absorption : α = 11 dB

Geometry : β = 6.2

50 dB

$$G_{1030} = 0.25\,G_{976} + 0.72\alpha_p\beta$$

Boullet et al., OE **16,** 17891 (2008)

Conclusions

1. **Demonstration of a ultra high power Yb fiber laser source**
   a) Single mode TEM_{00} : $M^2 = 1.2$
   b) Zero line transition at 977 nm
   c) Output power : 94 W (pump power limited)
   d) Large core Yb-doped microstructured rod type fiber
   e) Very compact and simple setup
2. **Analysis through numerical simulations**
   a) Pump absorption and population inversion
   b) Pump recycling
   c) Influence of the core diameter

Boullet et al., OE **16,** 17891 (2008)

Outlooks

1. **Applications**
   a) Core pumping of Yb or Er doped fibers
   b) High fluence pumping of Yb doped bulk material
   c) High power high quality pumping of Yb doped bulk material
   d) Frequency conversion -> high power high brightness sources at 488 nm
2. **Further studies**
   a) Q-switch
   b) Single frequency
   c) Frequency doubling