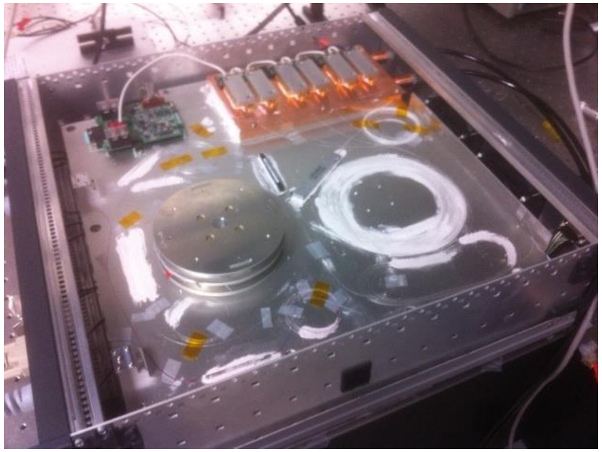
Fiber Lasers: Fundamentals and Applications

Lecture 1

V R Supradeepa

Center for Nano Science and Engineering (CeNSE)

Indian Institute of Science



Personal Background

Indian Institute of Science (Aug 2014 -)

Assistant Professor, Centre for Nano Science and Engineering

Research: Fiber Lasers, Silicon Photonics, Optical Communications

OFS Laboratories (Feb 2011 – July 2014)

Optical Fiber Solutions division of Bell laboratories spun off in 2002 into a separate R&D center

Research Scientist

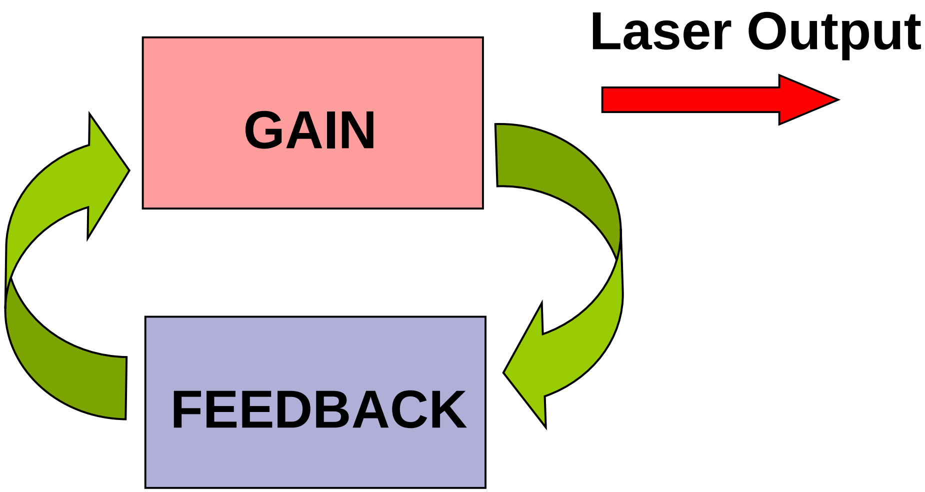
Research: Fiber Lasers, Nonlinear Fiber Optics

Purdue University (Aug 2006 – Jan 2011)

PhD in Electrical and Computer Engineering

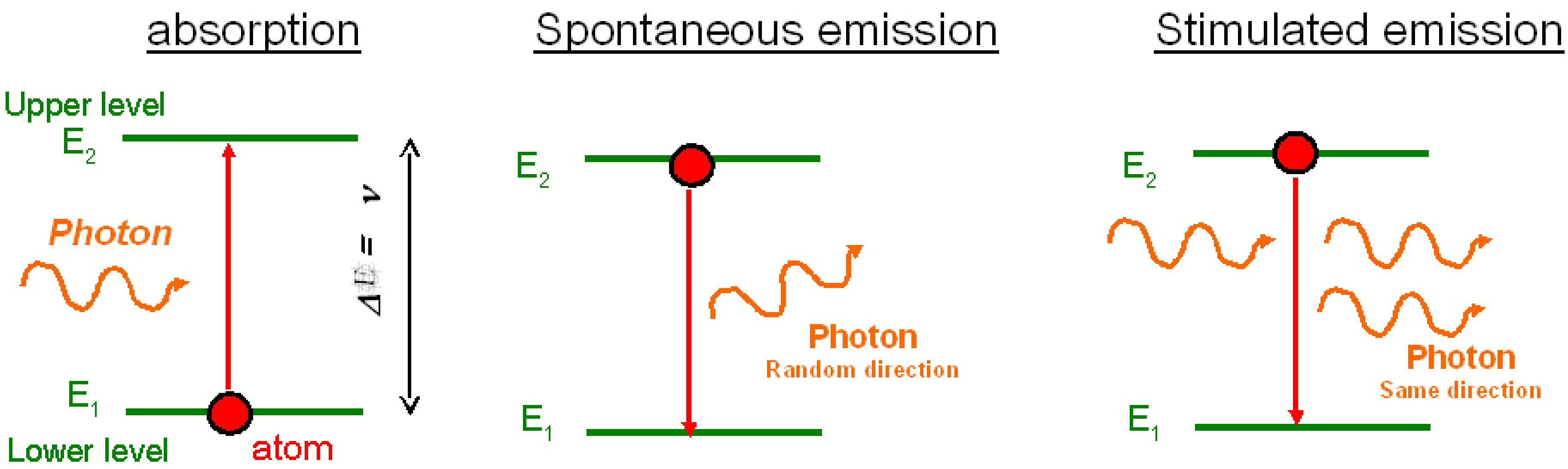
Research: Optical signal processing and characterization, Microwave Photonics, Frequency Combs and Metrology (Advisor: Prof Andrew M. Weiner, dept of ECE)

Lasers: Operating Principle

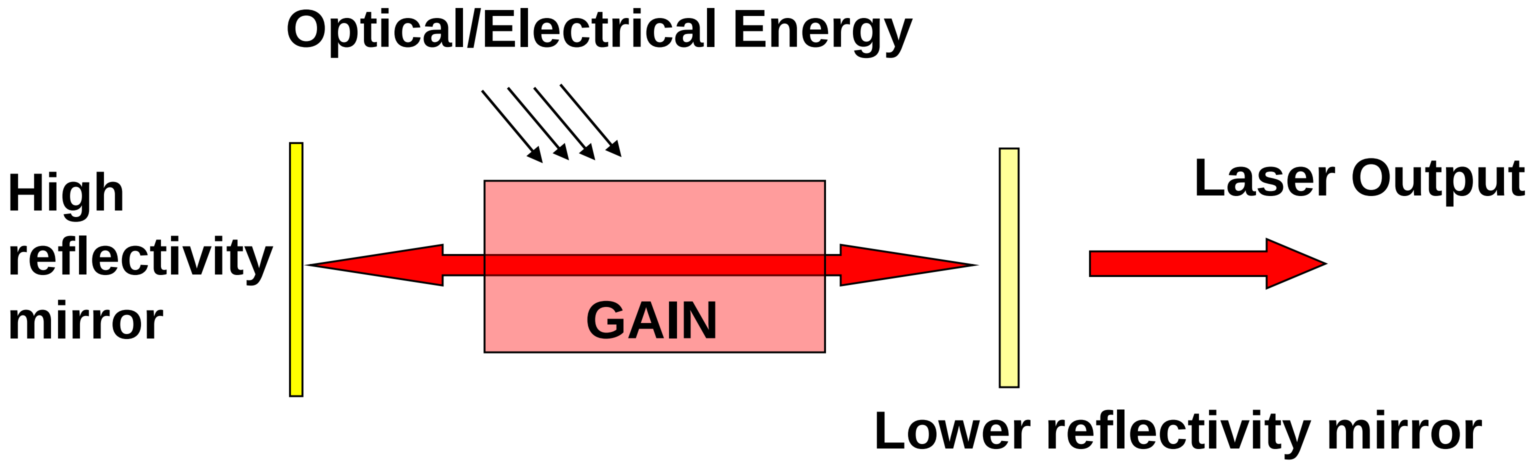


A Laser is basically an optical feedback oscillator

Spontaneous and Stimulated Emission



Feedback



Various other types of feedback possible

A brief history of lasers

Albert Einstein – 1917 (Stimulated Emission)

- Laid the foundation for lasers

Charles Townes, Jim Gordon, Arthur Shawlow (Columbia)

- Laser theory, Masers, credited for invention of masers

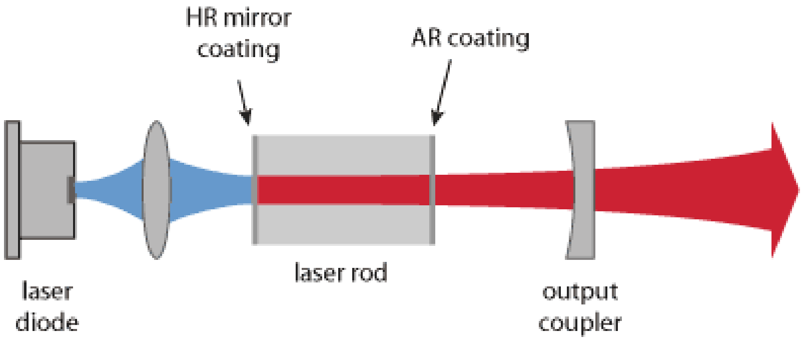
Gordon Gould (1959)

- Patent on fabry – perot resonator for lasers, came up with the word laser

Ted Maiman (1960) – First Laser (Ruby)

High Power Laser Technologies

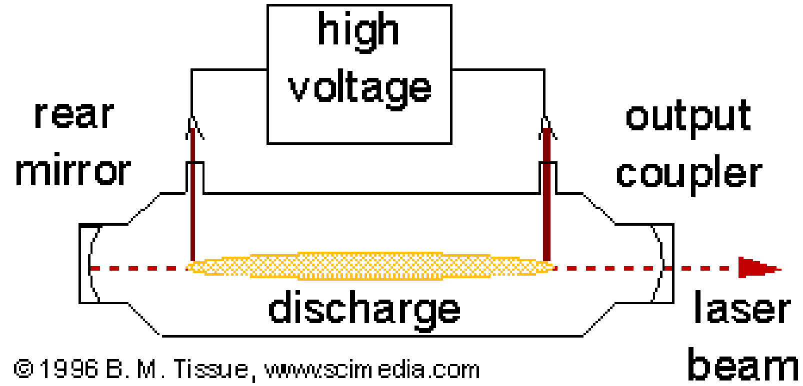
Solid State Lasers



Thermal limitations – causes beam degradation

Efficiency

Carbon-di-oxide Laser



Low efficiency

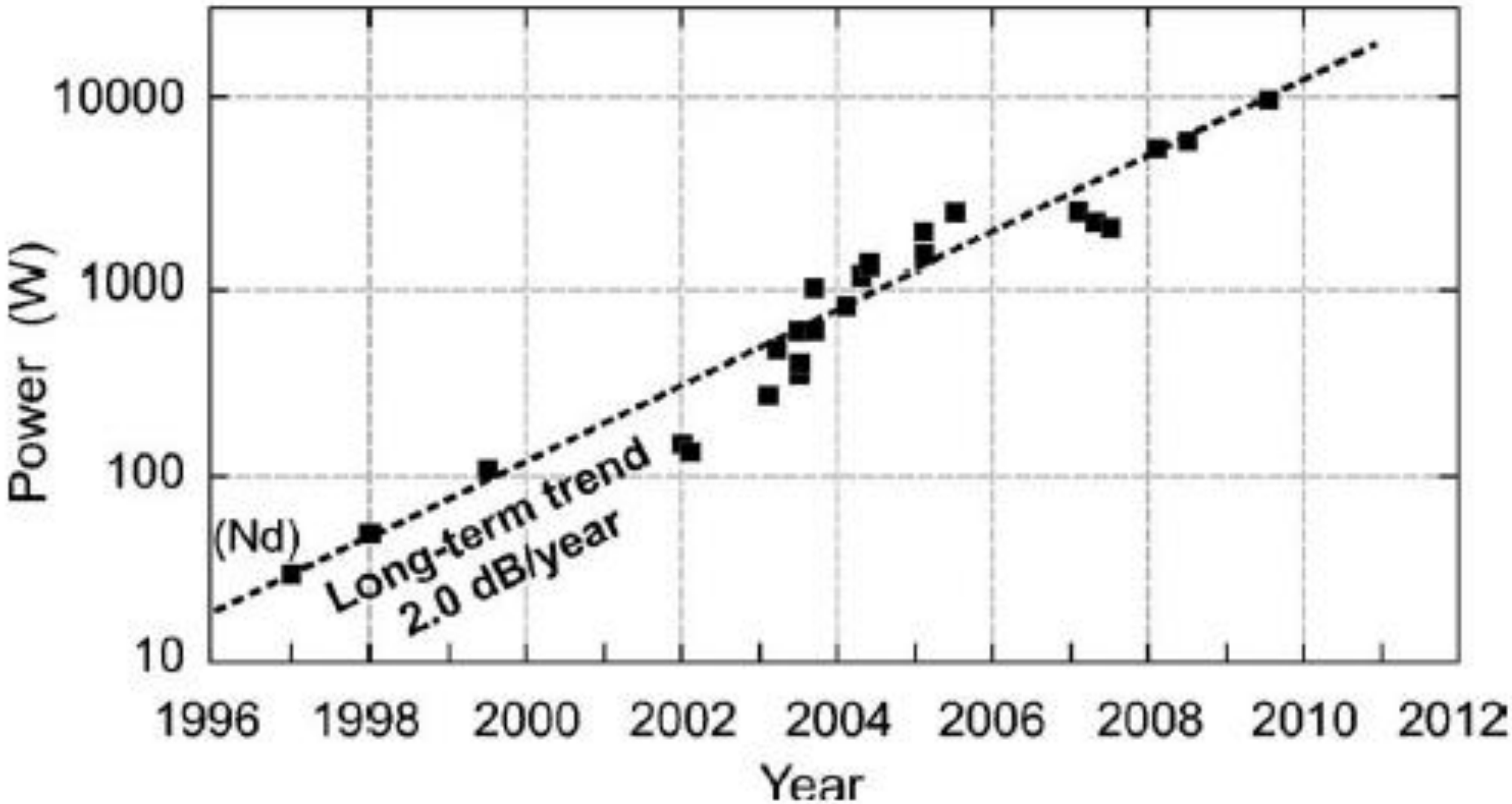
Continuous Maintanance

Large form factor

Fiber Lasers

From encyclopedia of laser physics and technology

Fiber Lasers



Why High Power (Fiber) Lasers ?

Industrial

- Material Processing
  - From automobiles to semiconductors

Medical

- Laser surgery

Defence

- LIDAR
- Directed Energy

And many more

Fiber Lasers in Action

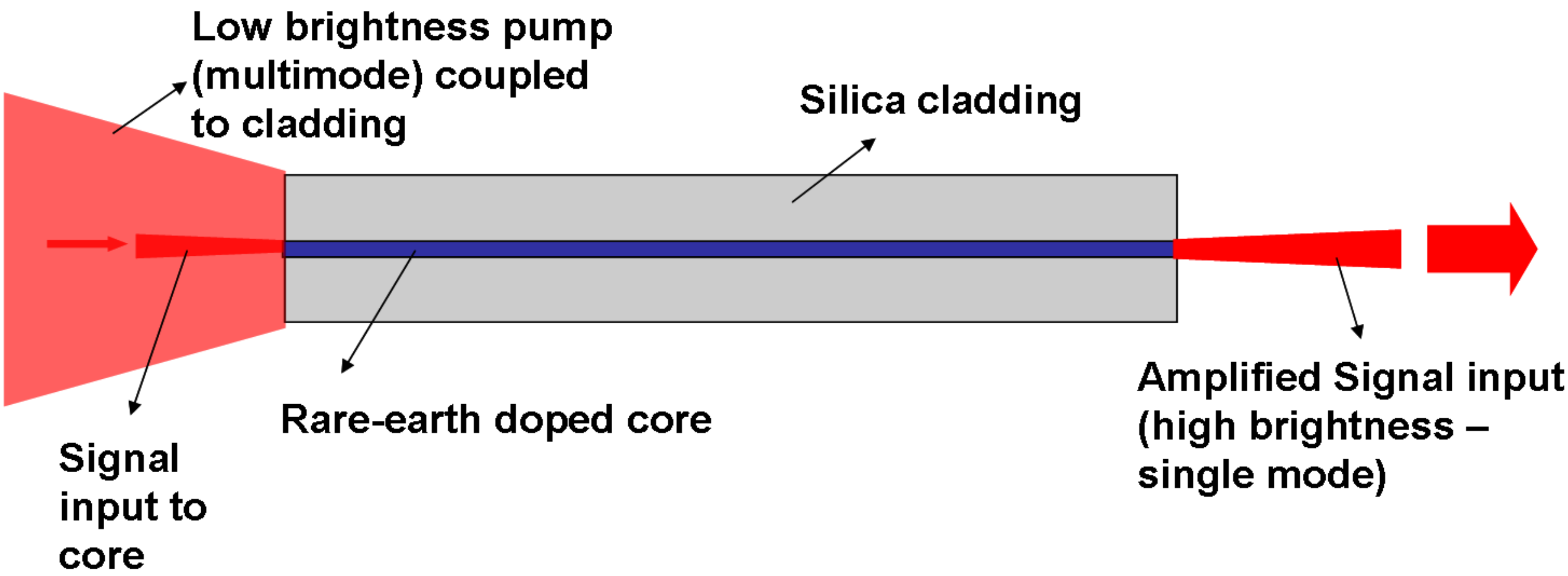
Our Sun ~ 100 W per sq ft (0.1 square meter)

This Laser transmits light in an area of 10^-11 square meter

What does this mean ?
This source is just a little brighter than our sun –
by 10000000000 times !

In a camera sensitive to IR wavelengths

High Power Rare-earth doped fiber lasers

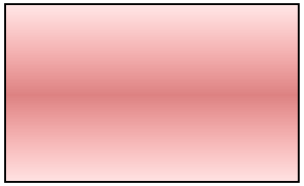


The rare-earth doped core absorbs and reemits the pump light into a high brightness beam (multimode to singlemode conversion)

Why Fiber Lasers ?

Distributed heat load

Bulk

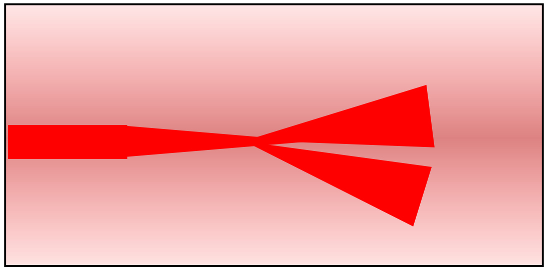


Fiber

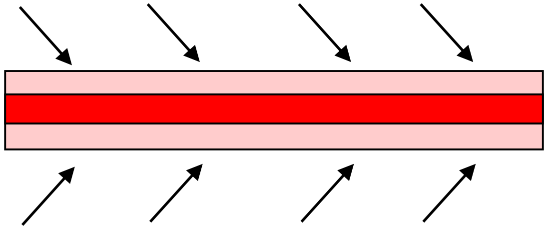
For a long cylinder – Area/Volume ~ (r/L)

Waveguiding

Bulk



Fiber

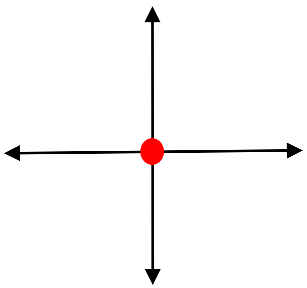


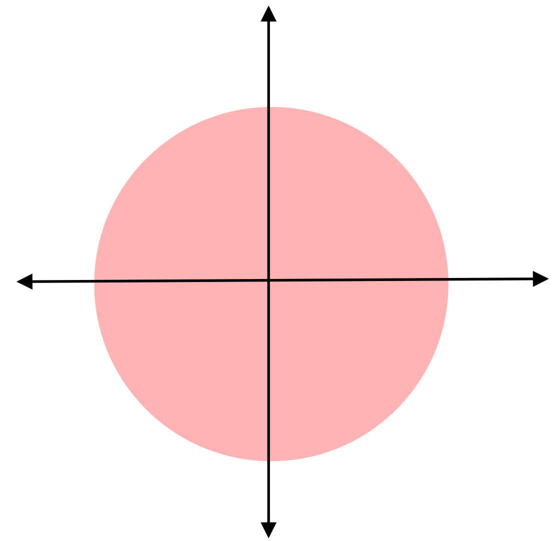
Single Mode or Multimode

Single Mode Light

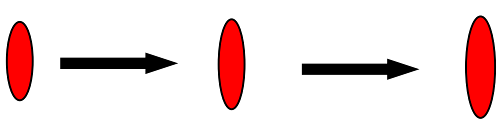
Highly Multimode Light

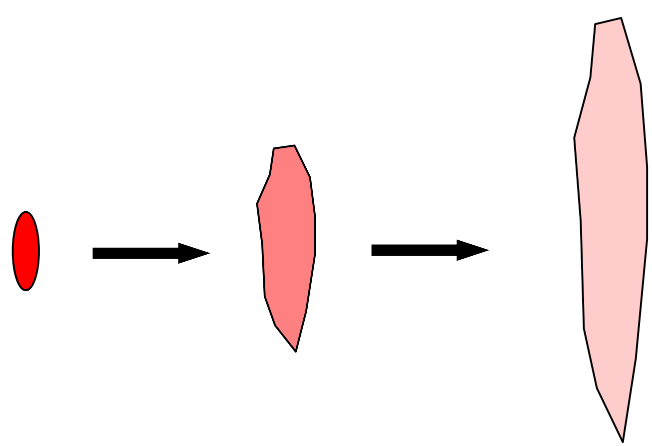
Focussed spot





Propagation





High Power Fiber Lasers as Brightness Convertors

A 1W laser which can only be focused to 1mm beams

- More of a heater than anything else

A 1W laser which can be focused to a 1micron spot

- Can cut metal

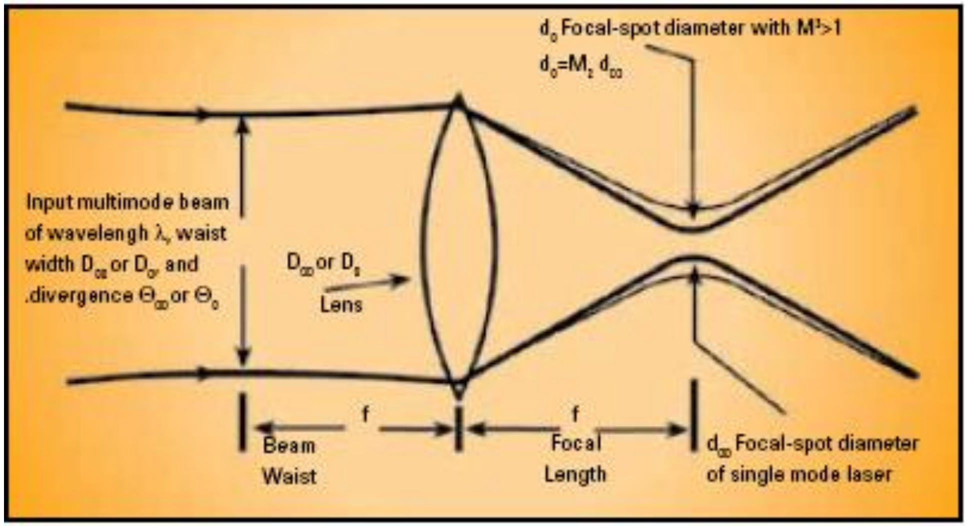
Fundamentally, fiber lasers or most optically pumped high power lasers are brightness convertors.

Characterizing the brightness of a beam

How do we characterize the true brightness of a beam ?

A Gaussian beam is optimal for free space propagation, diffraction limited.

Brightness is characterized by how Gaussian like the beam is.



M^2 value characterizes the beam

$$\theta = M^2 \frac{\lambda}{\pi w_0}$$

A brief history of fiber lasers

Ted Maiman (1960)

- First laser

Elias Snitzer(1961)

- First fiber laser, 30micron core, 300 micron cladding

However, after this it went no where for a long time … why ?

What happened to Fiber Lasers after their invention ?

No important application

Optical communications, laser material processing were all at their infancy

Problems with pumping

Fiber lasers require pumping with other (albeit lower quality) lasers). Diode lasers were not there.

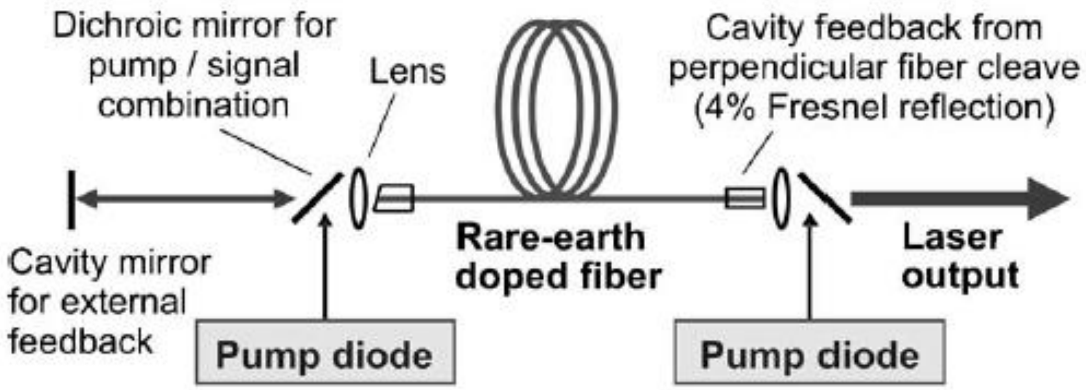
Flash lamp pumped solid state lasers were much better

What happened to Fiber Lasers after their invention ?

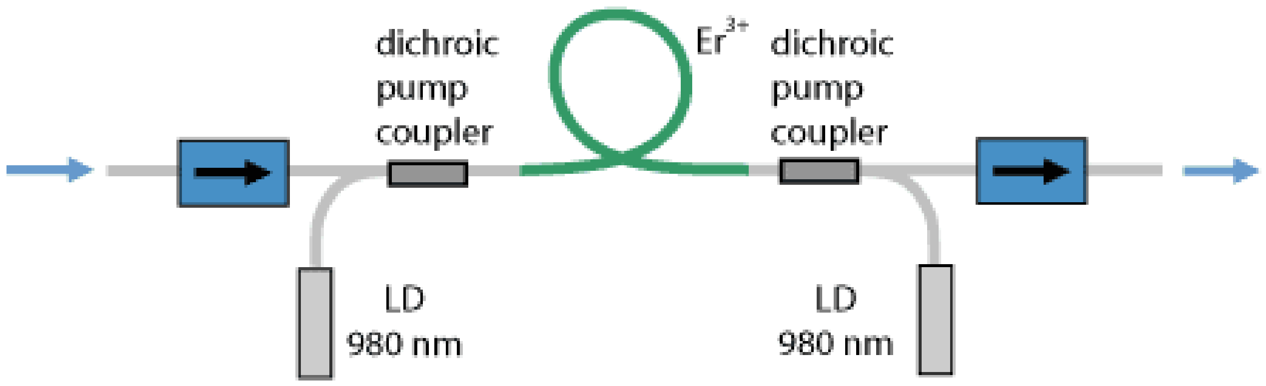
High Loss in fibers

Fibers had very high loss (15dB/m). Not sustainable

Problems with pump coupling



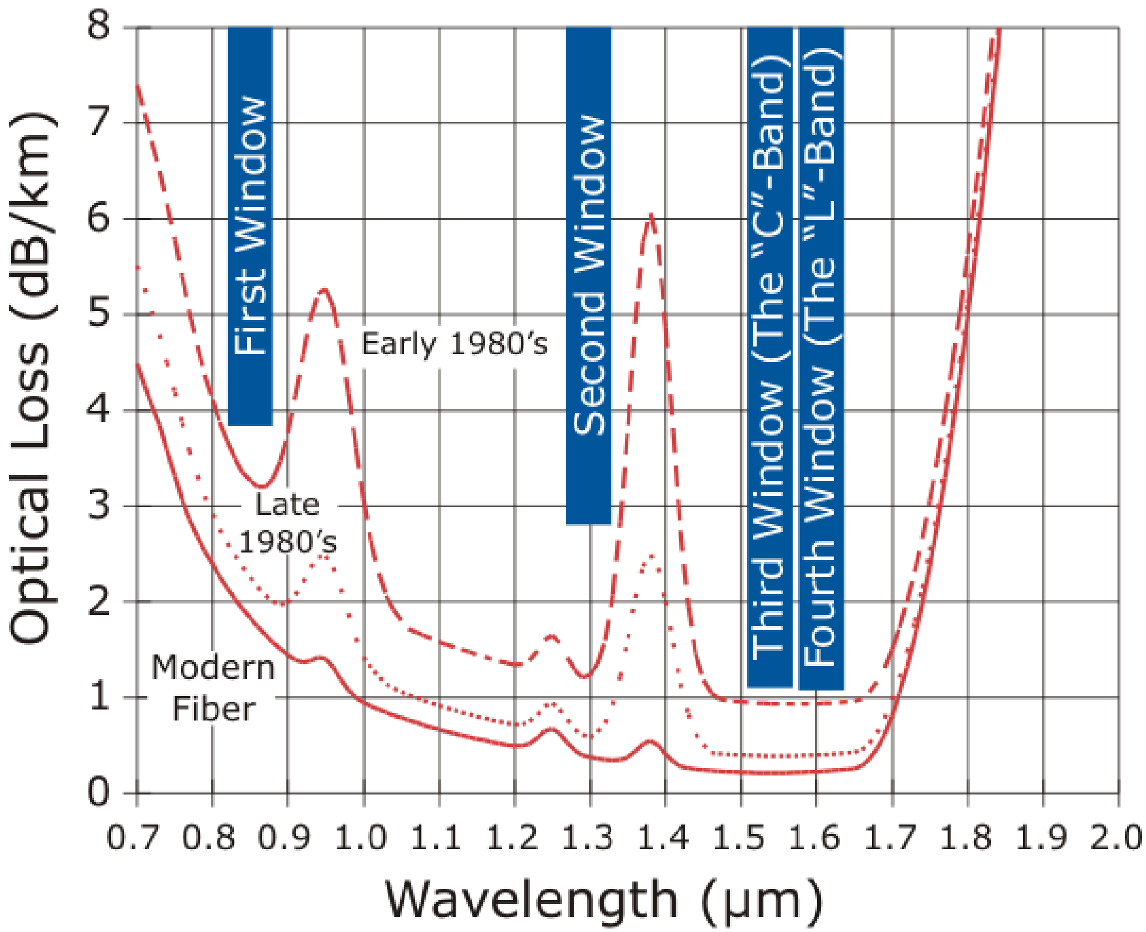
Invention of the EDFA



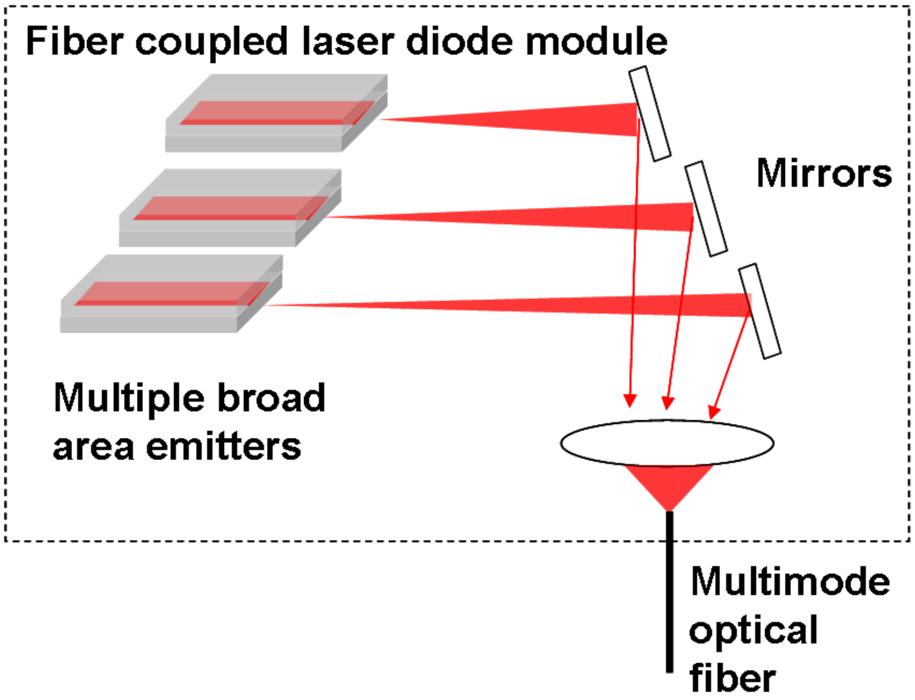
Powered the tremendous growth of internet

Advances made in amplifier development, components, doped fibers etc applied well to high power fiber lasers

Low Loss Fibers



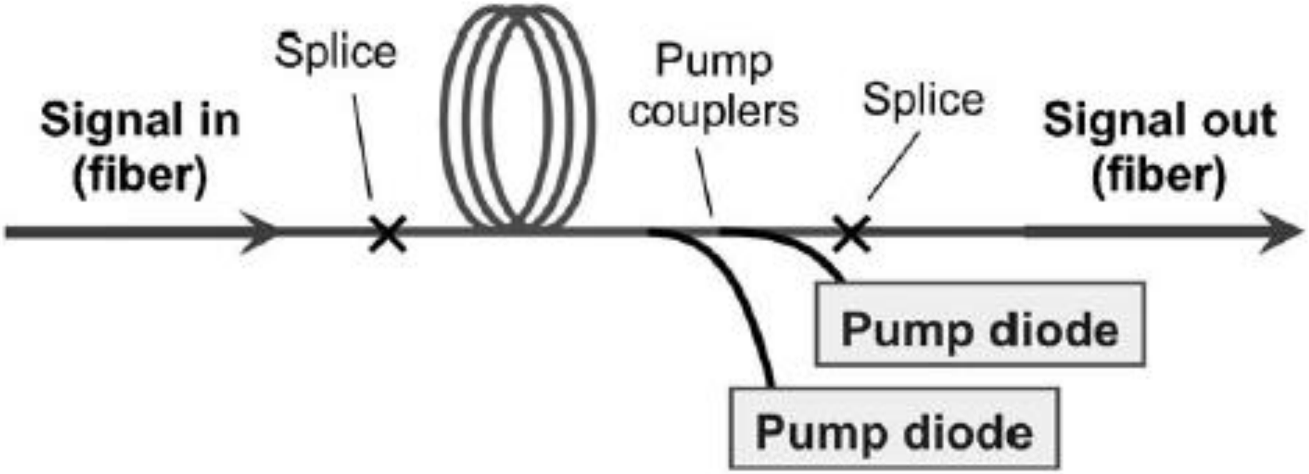
Development of high power pump diodes



Over 100W modules routinely available in the market today

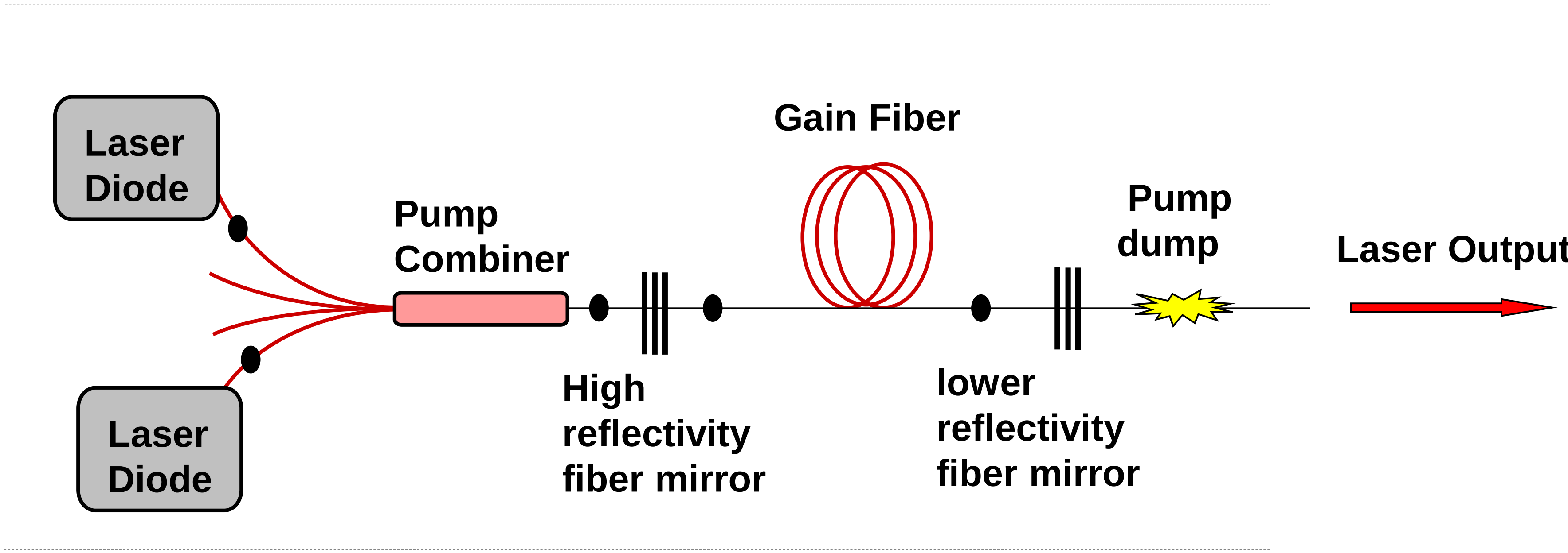
This was also applicable to solid state lasers

Better pump coupling



All fiber architectures – compact, robust, fiber delivery

Schematic of a Modern High Power CW Fiber Laser

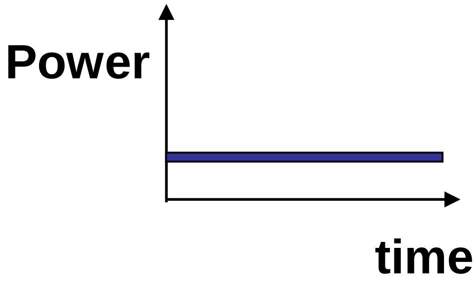


Classes of High Power/Intensity Fiber Lasers

Fiber Lasers

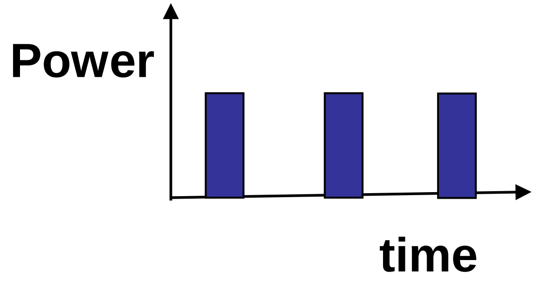
Continuous Wave

- High average power
- Lower light intensity



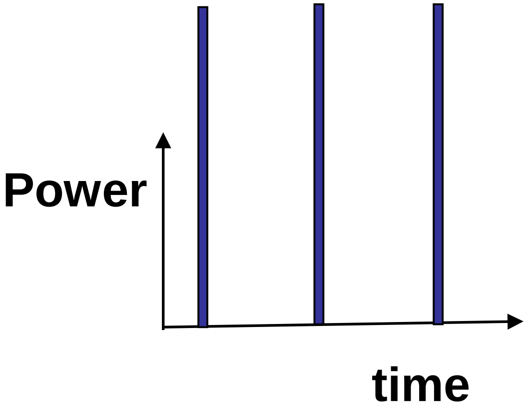
Pulsed (ns-ps)

- medium average power
- higher light intensity



Ultrafast (fs)

- Low average power
- Extreme light intensity



Classes of High Power/Intensity Fiber Lasers

Ultrafast

- Athermal processing
- Fundamental Physics
- ------
- Nuclear fusion

Pulsed

- Thermal (fine features)
- Tissue ablation
- LIDAR

Continuous wave

- Thermal material processing
- Defense
- Pump laser sources

atto **femto** **pico** **nano** **micro** **seconds**

Time scales