LMA Fiber Laser Building Blocks

Advances in
Fiber Devices
LASE2005

Jan 2005

Outline

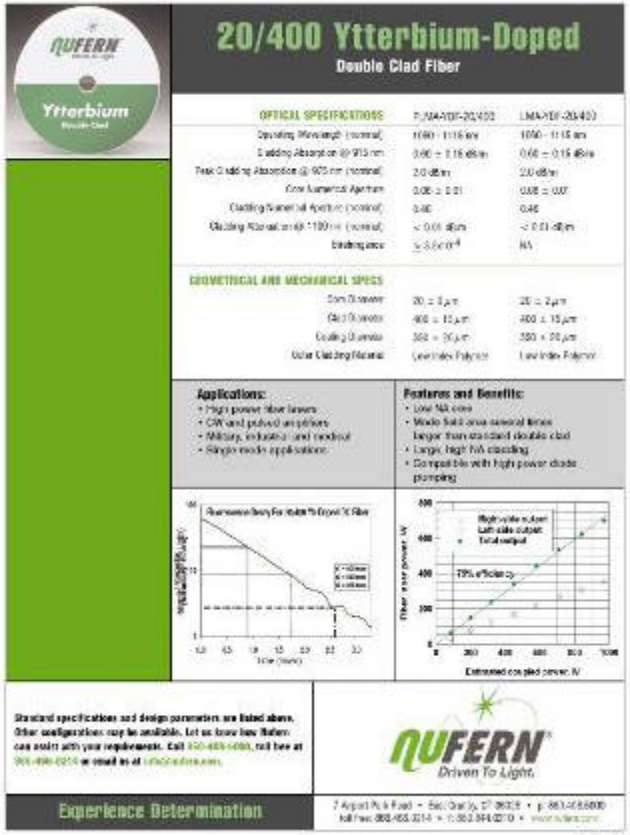
- Yb-doped fiber & gain-blocks
  - Progress on standard LMA fibers
  - LMA fiber Bragg gratings and couplers
  - Pump options (bars and single emitters)
- Recent results on **monolithic** LMA lasers/amplifiers
- Er:Yb-doped fibers at 1550nm
  - Progress on fibers and recent results
- Tm-doped fibers at 2μm
  - Progress on fibers and recent results
- Conclusions

Update on Yb-doped LMA fibers

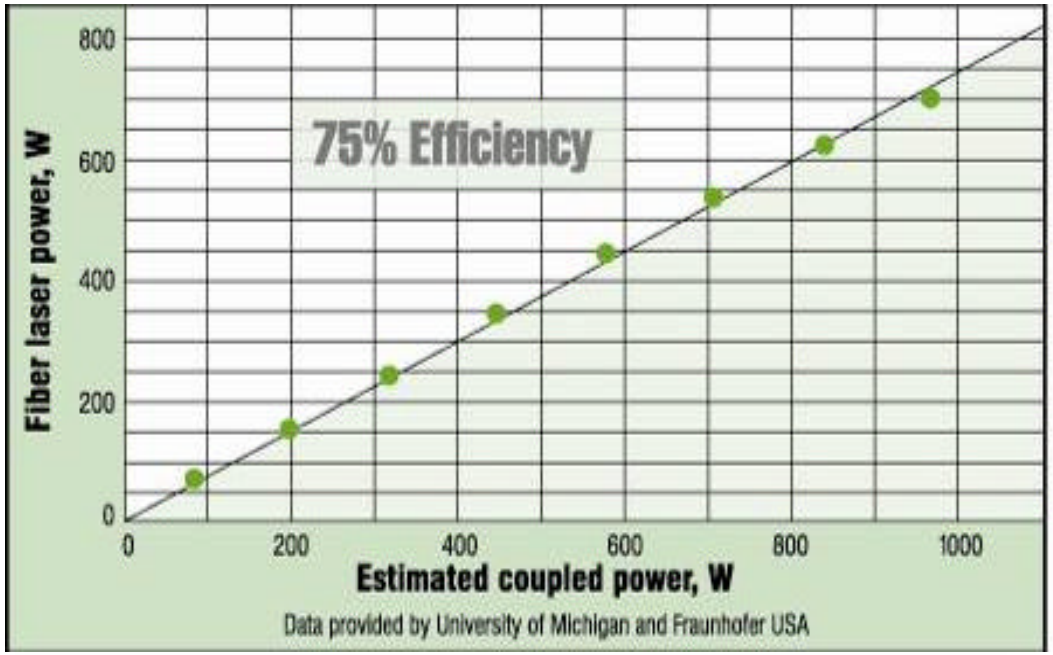
- ~10 standard LMA fibers have been introduced
  - ~30µm core diameter is largest "standard" to date
    - Capable of good beam quality in many practical applications
    - However, many interesting things are being done with 20µm core
- Custom fibers
  - ~50µm core has received a lot of attention
    - Whether this can deliver good beam quality under practical deployment conditions remains to be seen
  - Custom up to ~200µm core
  - New waveguide designs (LFM)

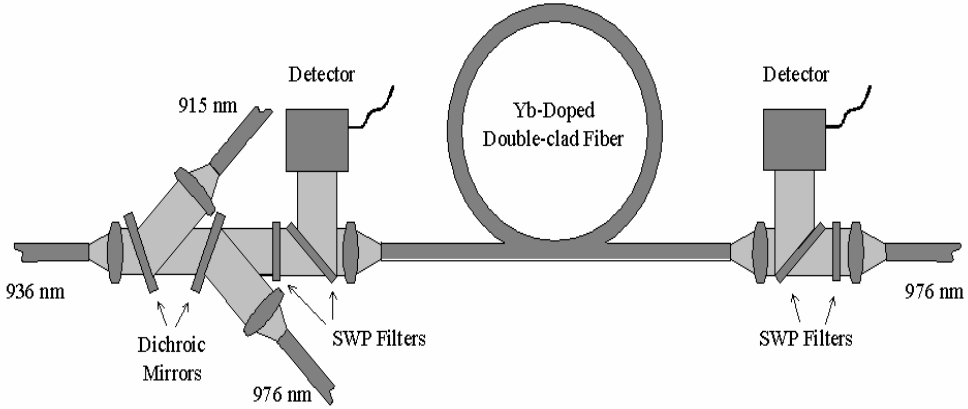
Yb-doped LMA “Standard” fibers

20µm core, 0.06NA
V~3.7 at 1080nm
Core supports two modes
Easy to deliver good beam quality
Large cladding enables various pump options

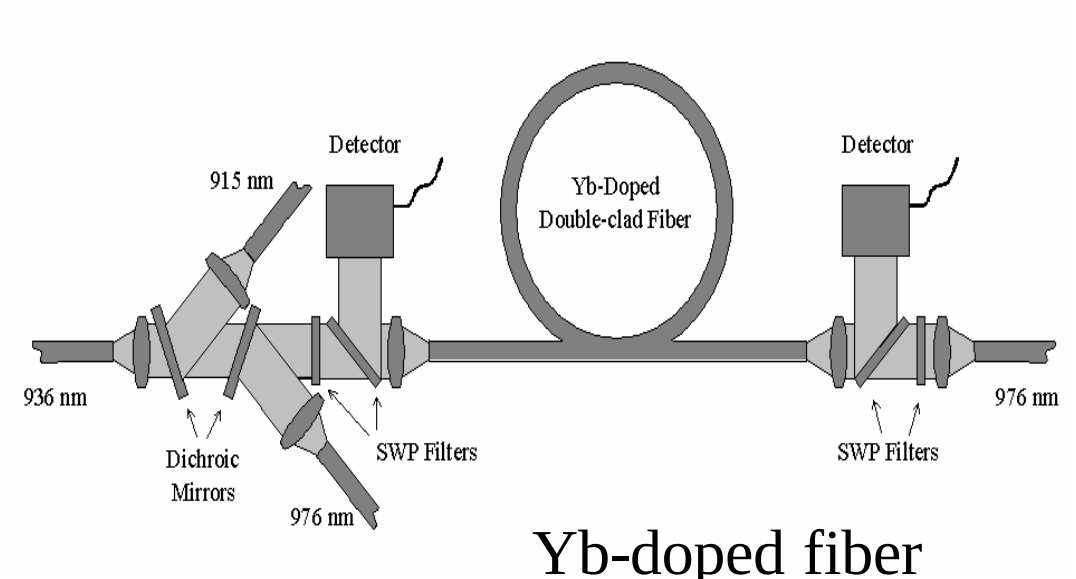


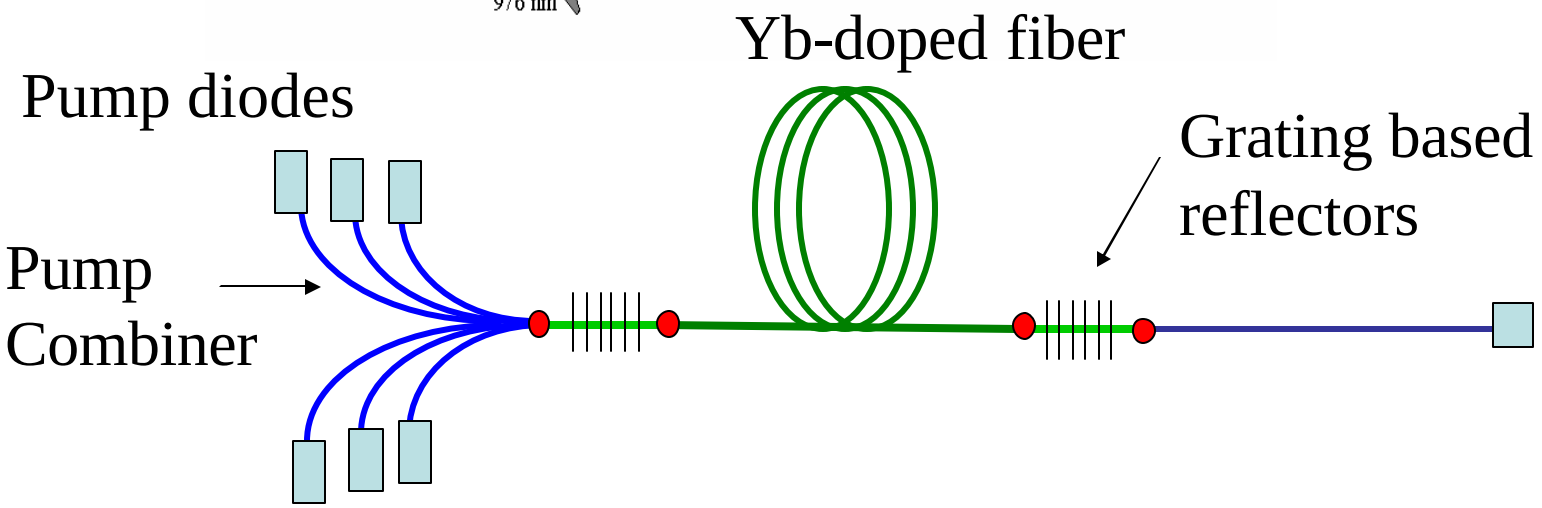
20/400 fiber is capable of very high power





What does it take to go from free space to monolithic LMA modules?

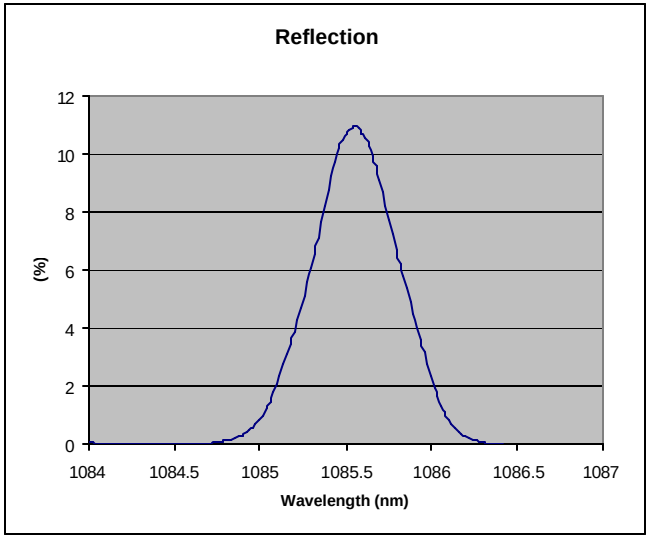




Photosensitive LMA fibers for Gratings

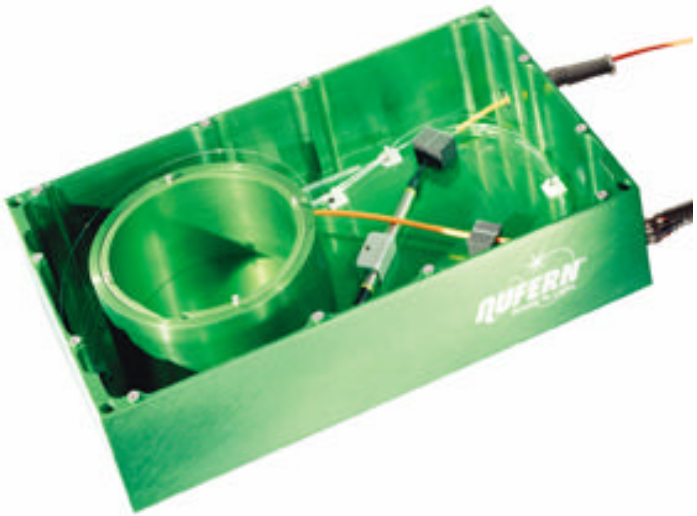
- Photosensitive fiber has to be well matched to By-doped
  - Low NA (~0.06) and high photosensitivity are very difficult to achieve simultaneously
  - Requires careful optimization of the fiber composition
- For low splice loss and low inter-modal excitation
- Stable gratings at high power

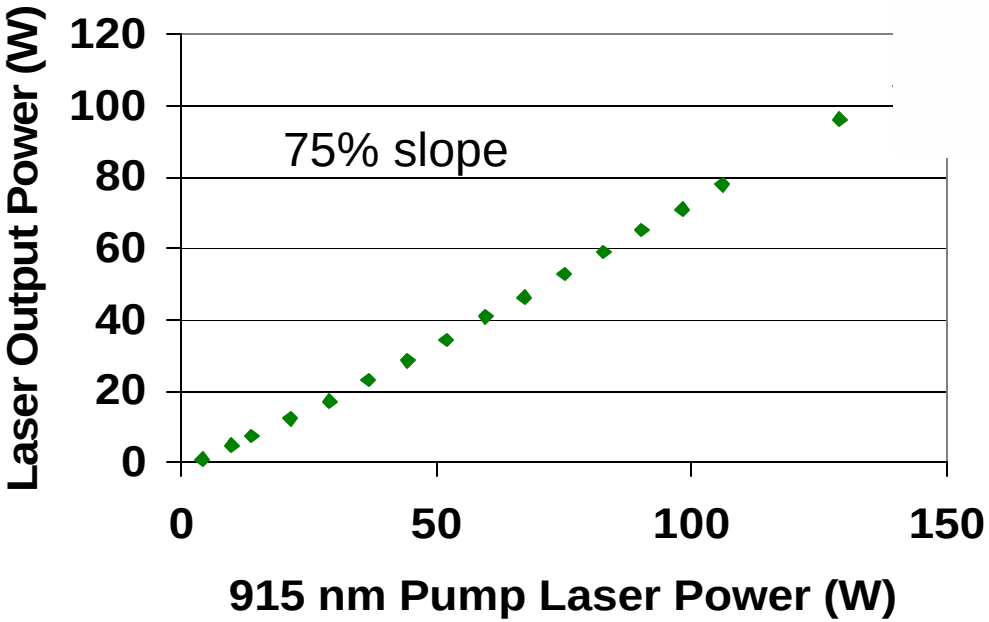
Characterization of the gratings can be difficult
Due to cladding light and mode coupling



LMA fiber Gratings and LMA lasers

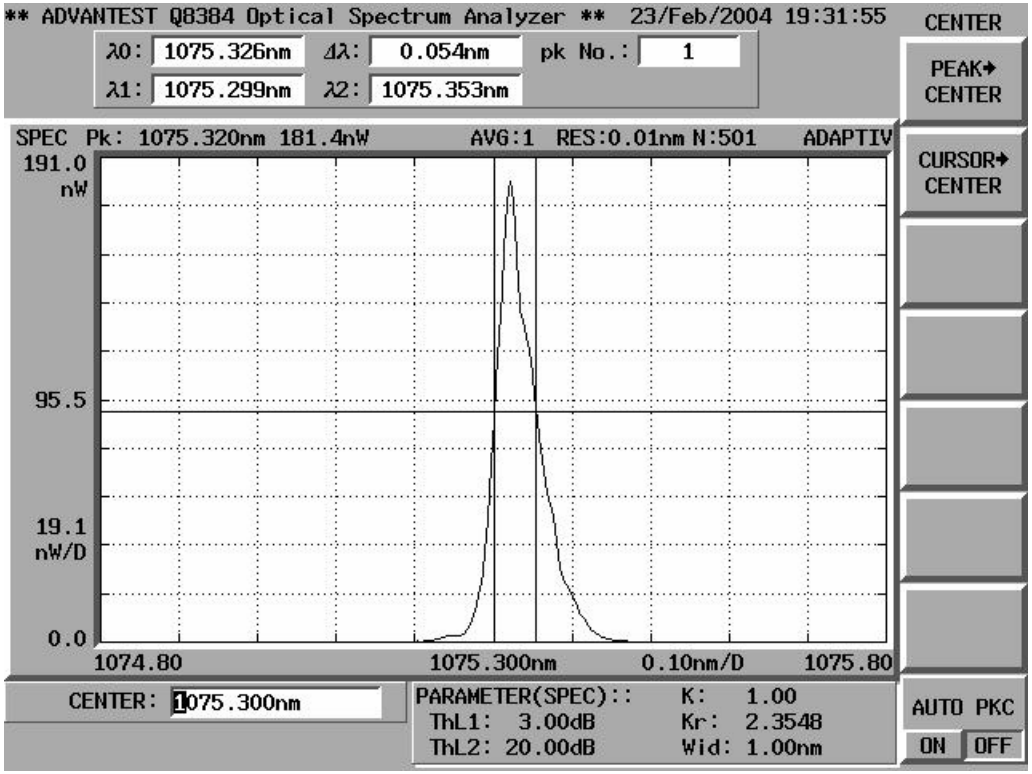
20/400 module with optimized coil f





High Power, Narrow linewidth lasers

~120W, 0.055nm linewidth



Experience Determination

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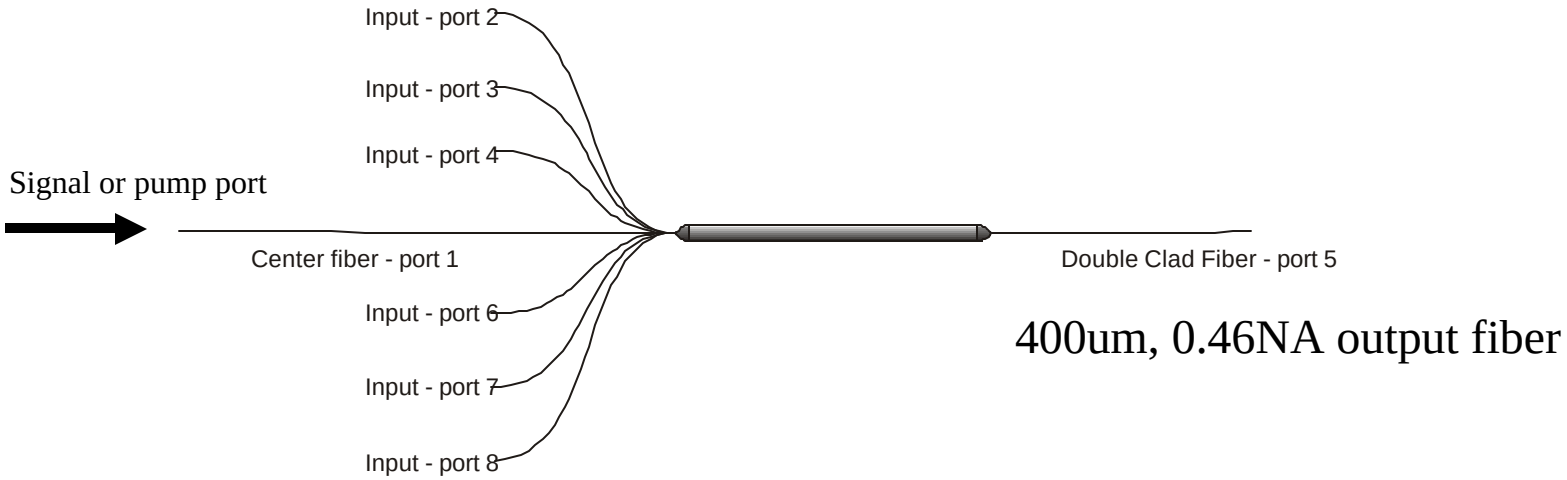
High Power LMA Combiners Options



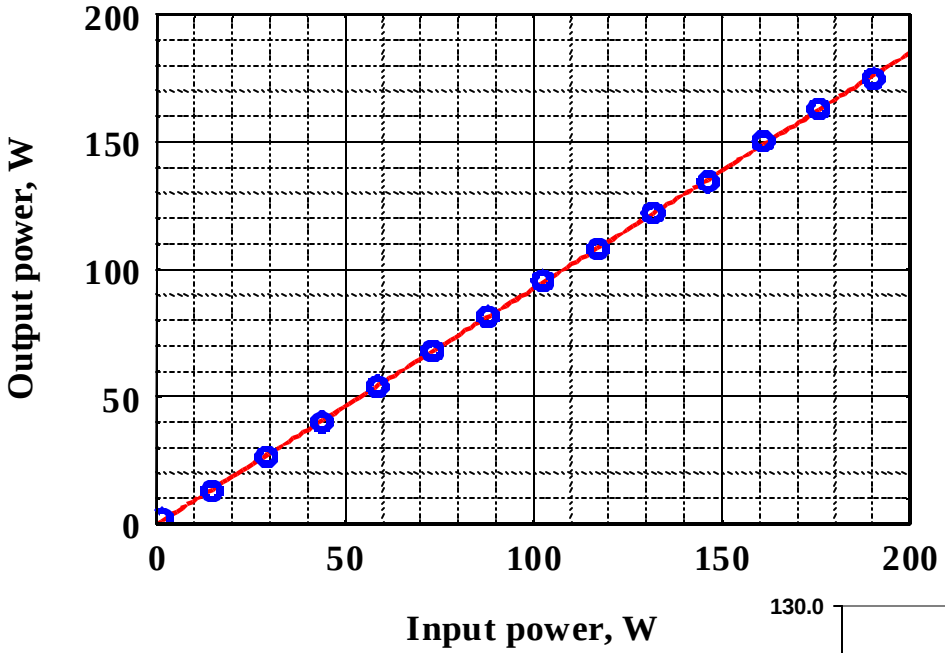
- A flexible pump technology that is compatible with
  - 105/125, 200/220 and 400/440 delivery fibers
- Large, 400µm cladding makes this technology compatible with many pump options
  - Including diode bars and stacks
  - Typically delivered with 200 and 400µm fibers
- Also allows for pump redundancy

Some examples of available pump options

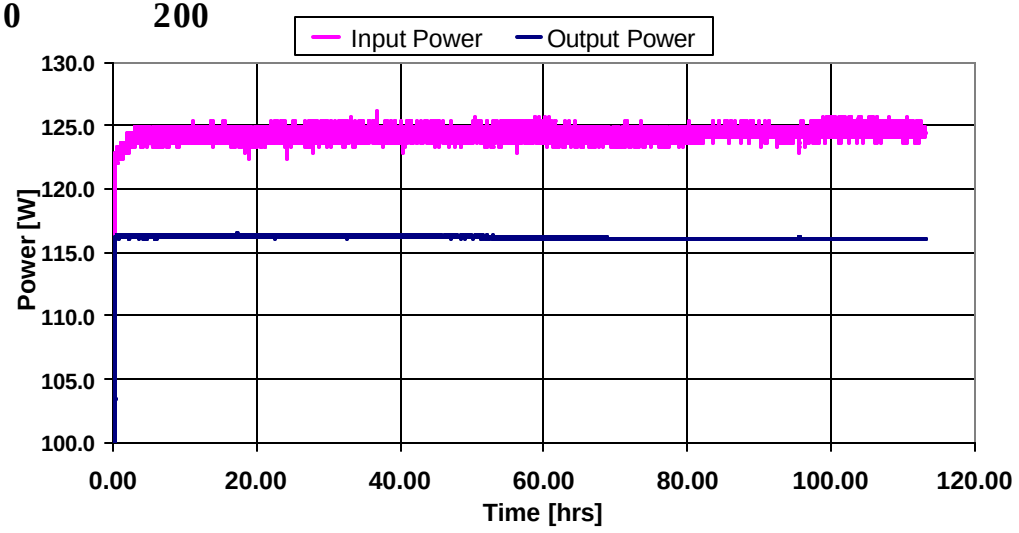
Input Fibers to the Combiner (core/clad)	Output Fiber (diameter and NA)	Typical (max) Number of Input fibers	Diode Pump Technology	Typical Power per Leg	Total Pump Power
105/125 0.22NA	400µm 0.46NA	19 (42)	pigtailed single emitter	3-5W	95W (180W)
200/220 0.22NA	400µm, 0.46NA	7 (7)	fiber coupled diode bars	10-50W	70-350W
400/440 0.22NA	400µm, 0.46NA	3 (3)	Fiber coupled bars and stacks	30-200W	90-600W

Flexibility in wavelength 915, 940, 975nm

High Power Coupler Test Data



Data Courtesy F. Gonthier, ITF



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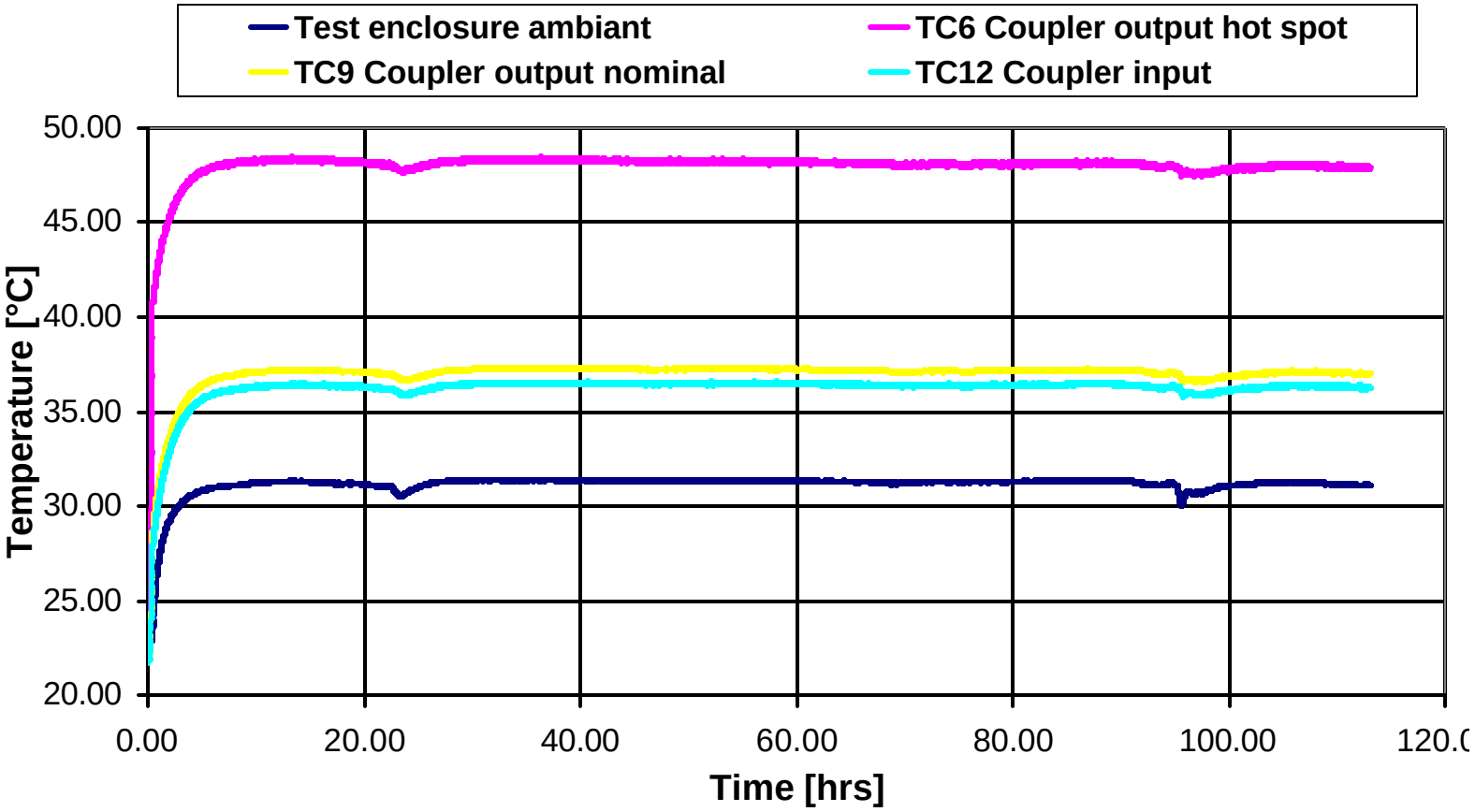


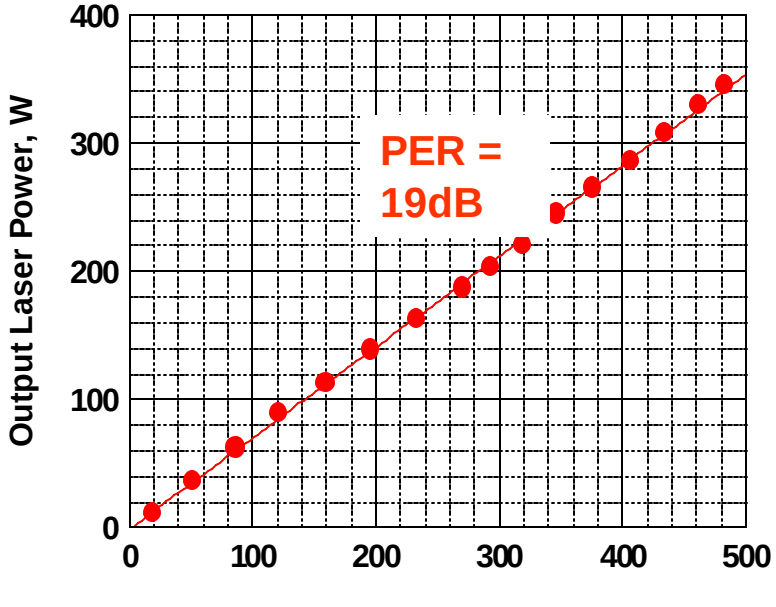
Data Courtesy F. Gonthier, ITF

Recent Results on monolithic LMA lasers and amplifiers

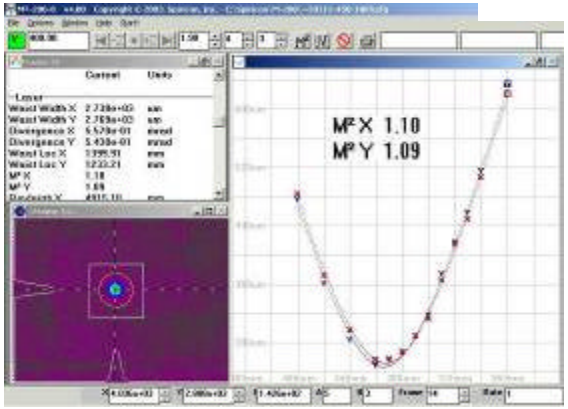
Recent results on grating based lasers

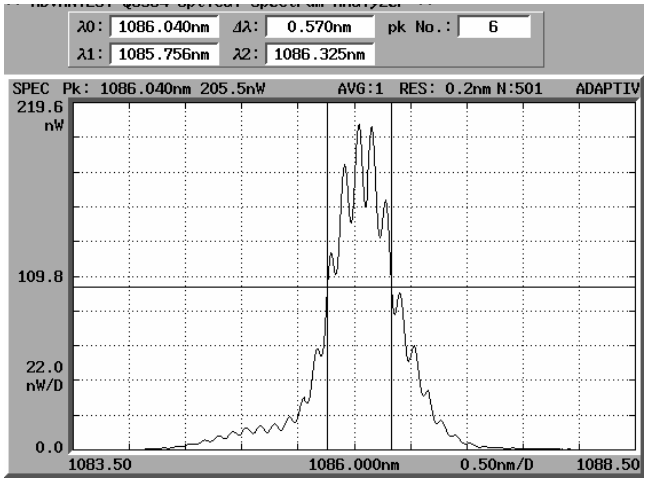
- Grating based cavities are desirable for a number of reasons
  - Efficient, no realignment, robust
- Provide extra degree of **wavelength** and **linewidth** control
  - The same fiber can operate ~1030-1120nm
    - Just change the pair of gratings
  - Wavelength and linewidth stability is much better
    - Critical for non-linear frequency doubling
    - Also for pumping solid state lasers

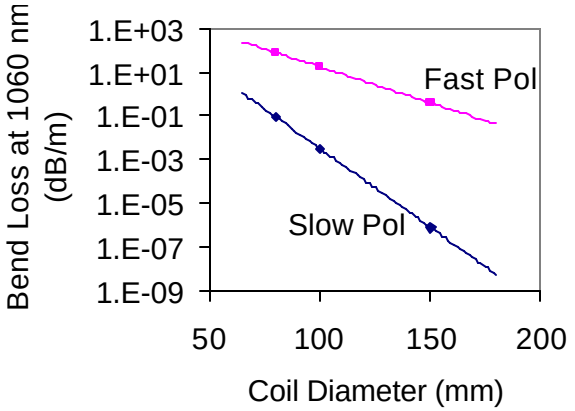
High Power Linear Polarized Laser



- M2 ~ 1.1
- Linewidth ~ 0.5nm
- PER ~ 19dB







Experience Determination

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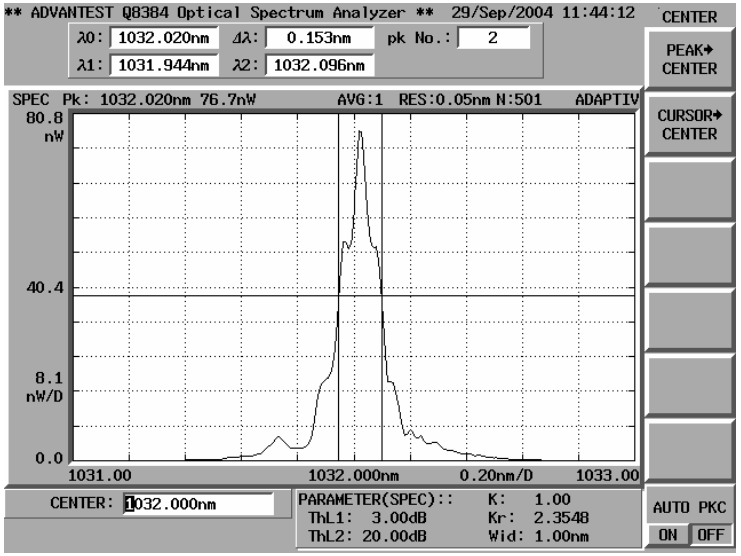
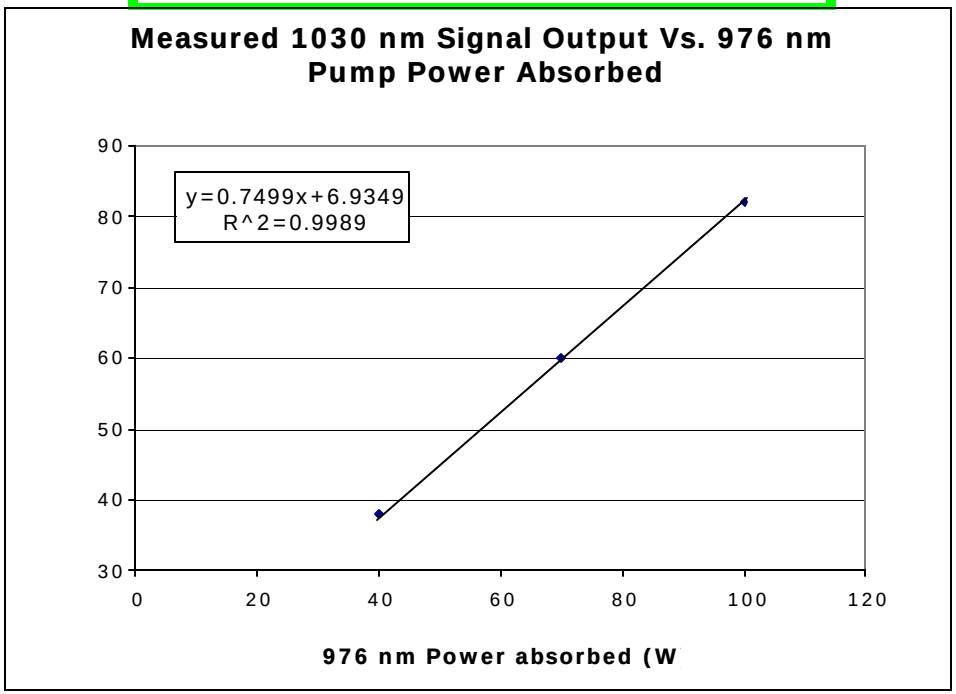
High power **1030nm** Laser (20/400)

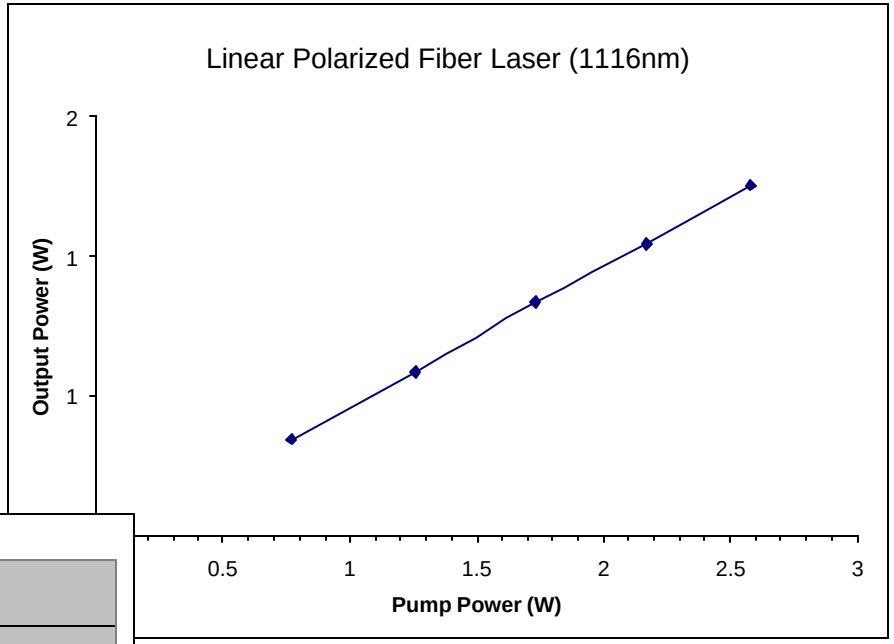
Output power **121.5W**
Coupled pump power 177W
Pump getting thru 24.6W
Lasing wavelength 1032nm
Spectral linewidth 0.15nm
Noise 0.7%

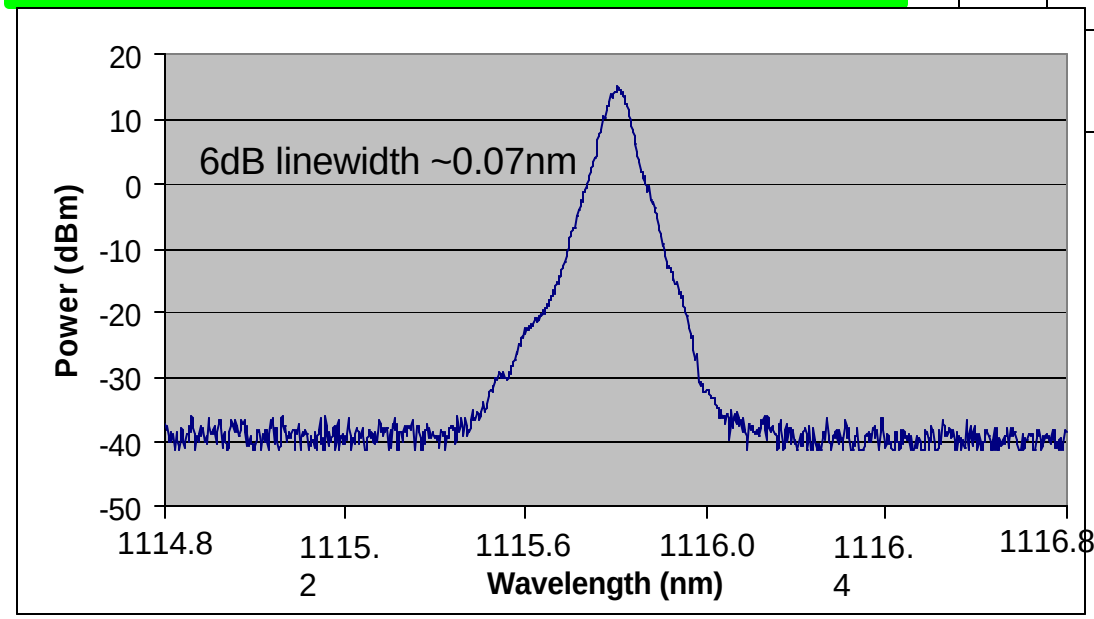




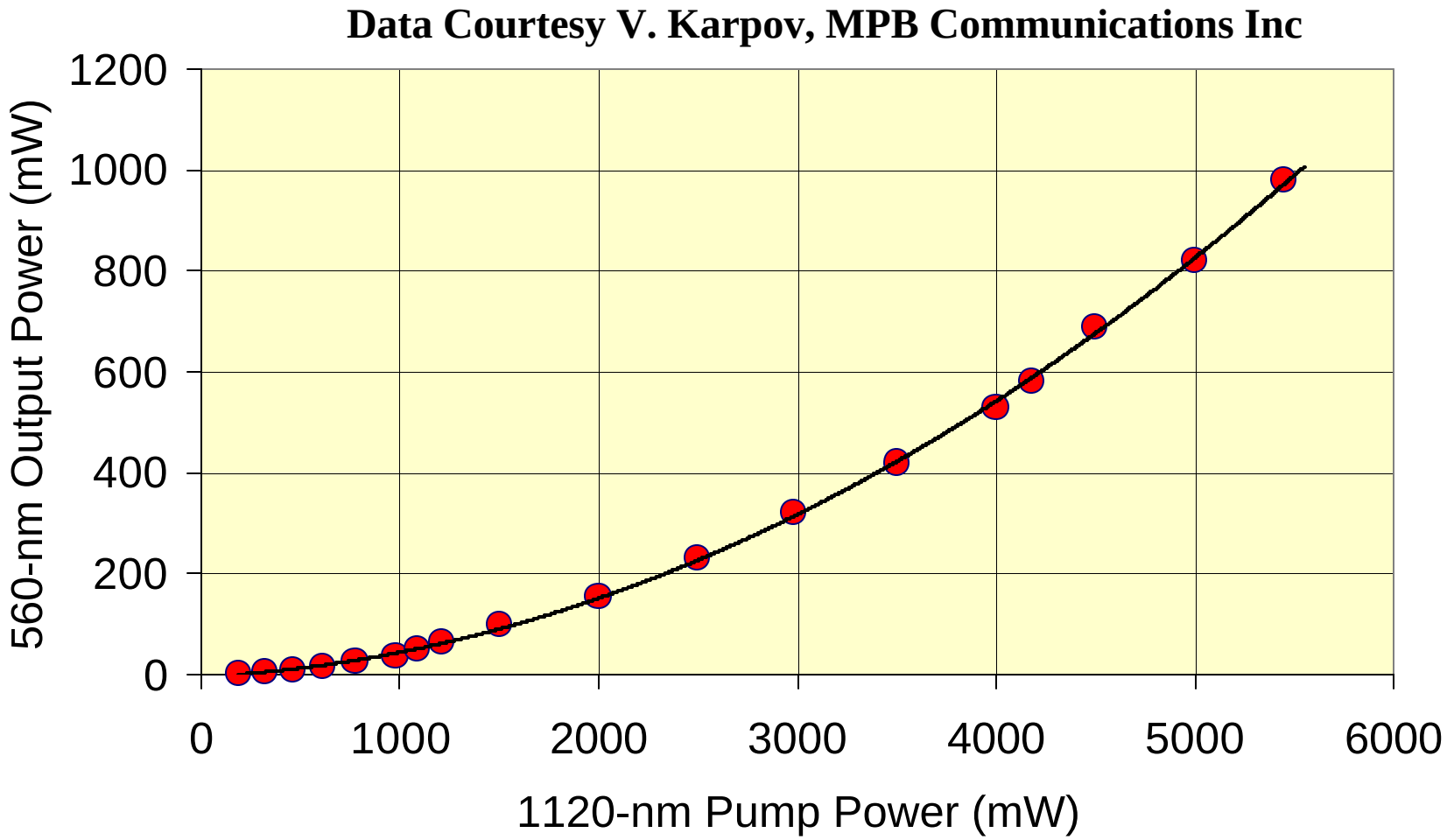
Linear Polarized Lasers

- **1116nm ~2W o/p power**
- Narrow linewidth (<0.07nm)
- Linear polarized
  - PER=17dB at 1W



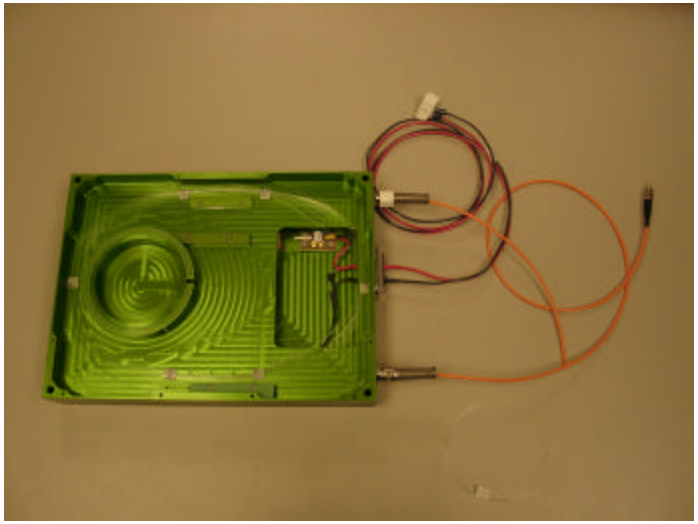


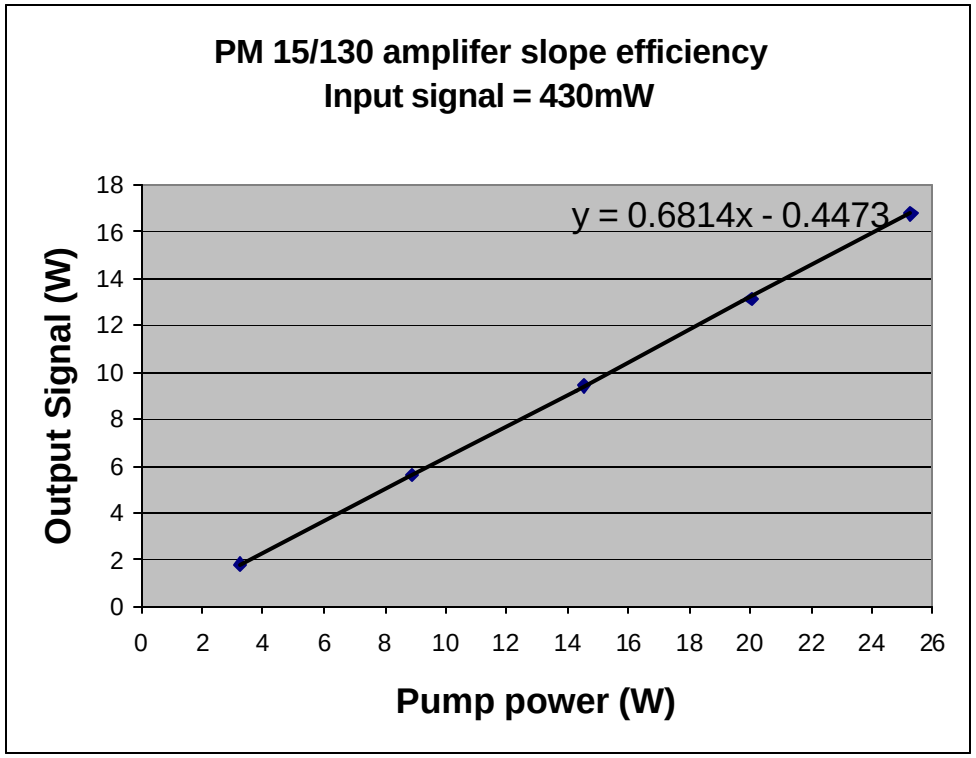
CW Second Harmonic Generation : 560-nm Output Power vs. 1120-nm Pump Power



PM-LMA Amplifiers based on 15/130 fiber

Input signal power 430mW
Output signal power 16.8W
Pump power 25.3W
Slope efficiency 68%
Signal wavelength 1047nm
M2 = 1.1
PER>16dB



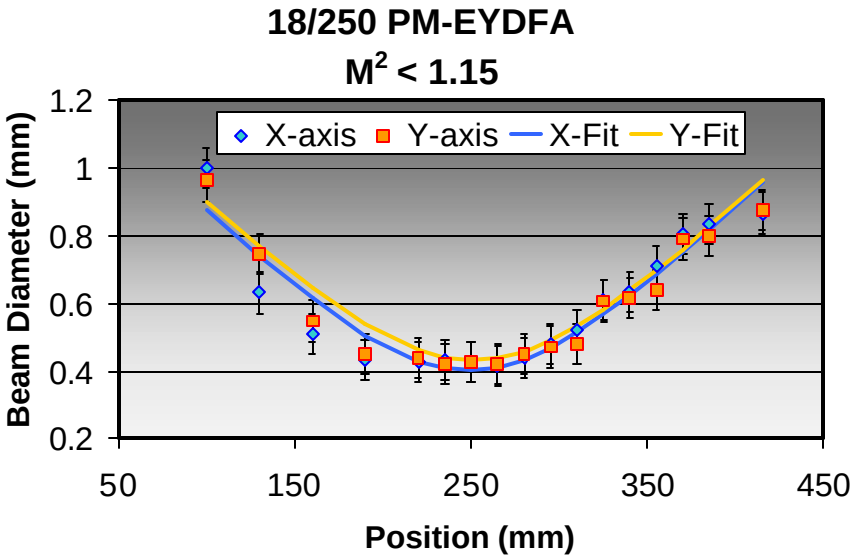


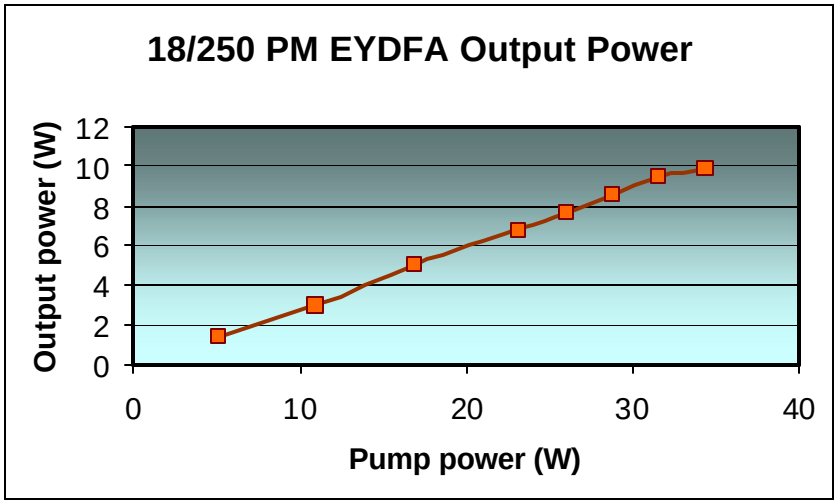
Development of fibers for 1.5 and 2μm operation

State of the art Er:Yb-doped Fibers

DATA Courtesy W. Torruellas, Fibertek Inc.

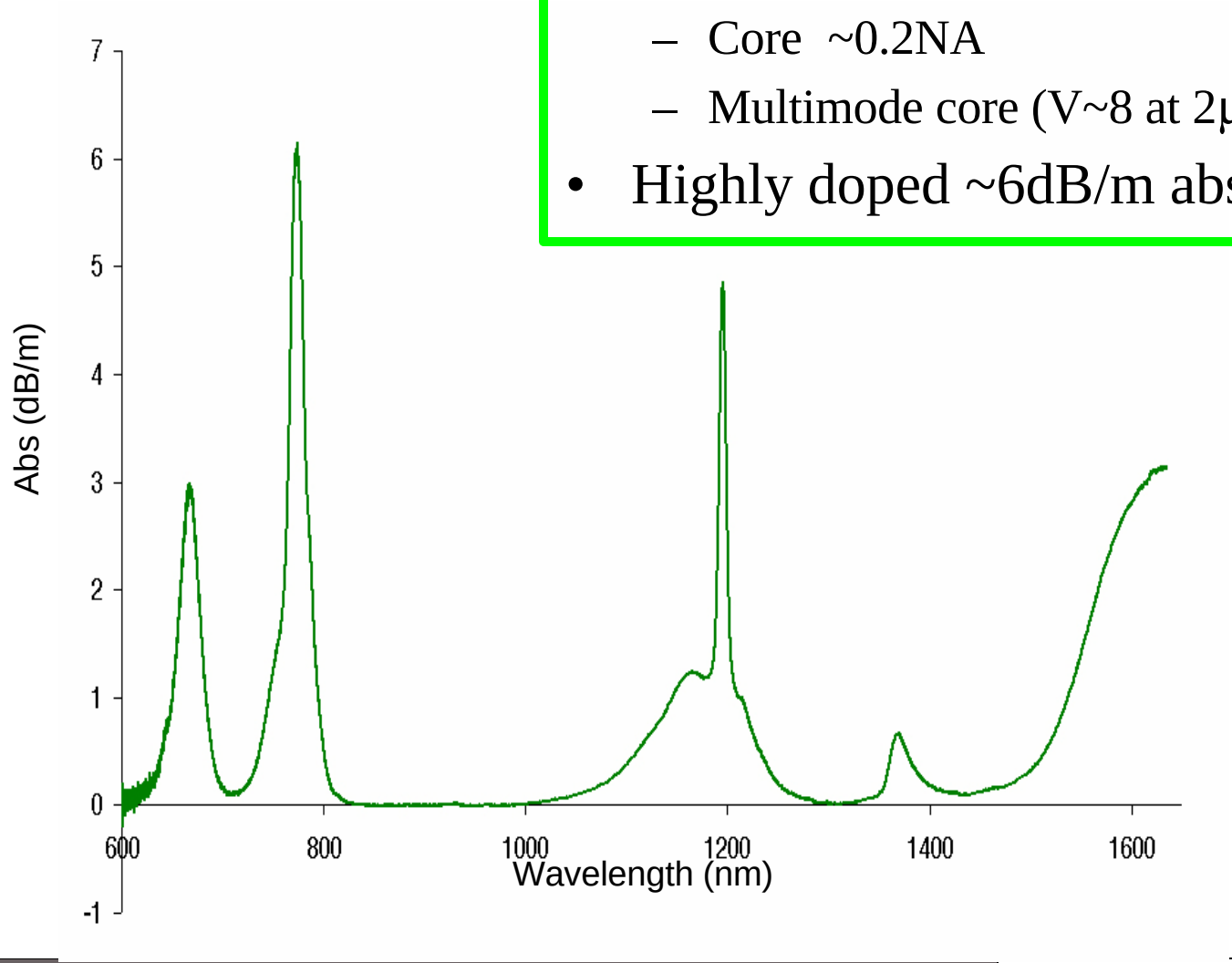
- PM-18/250 fiber
- Has delivered ~100 μJ pulses and P_{ave}~10 W
- 3 ns pulses, peak power > 30 kW (~ 65 J/cm2)
- Single mode output (M2 ~ 1.1)





Tm-doped fibers for 2µm operation

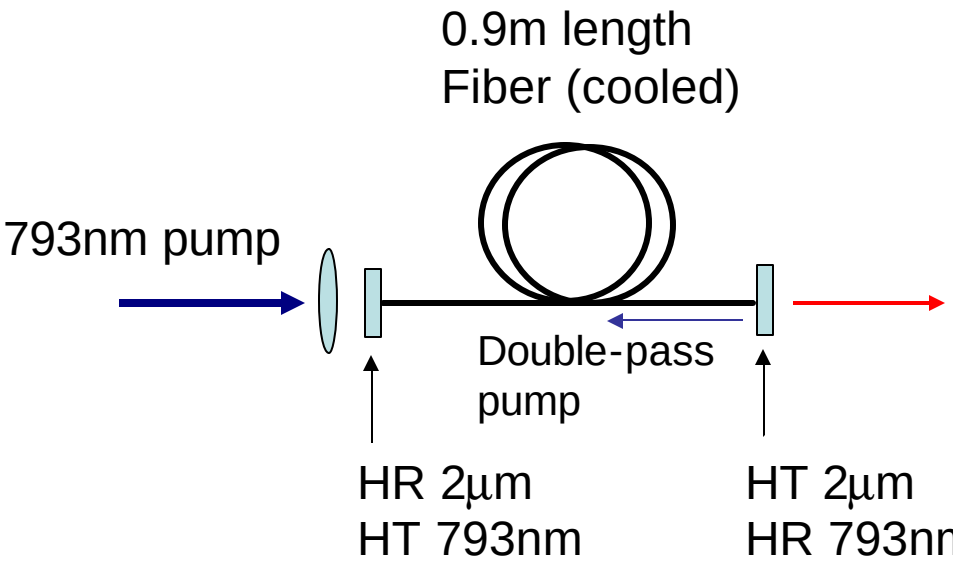
- Fiber Design 25/250
  - Core ~0.2NA
  - Multimode core (V~8 at 2µm)
- Highly doped ~6dB/m abs at 793nm

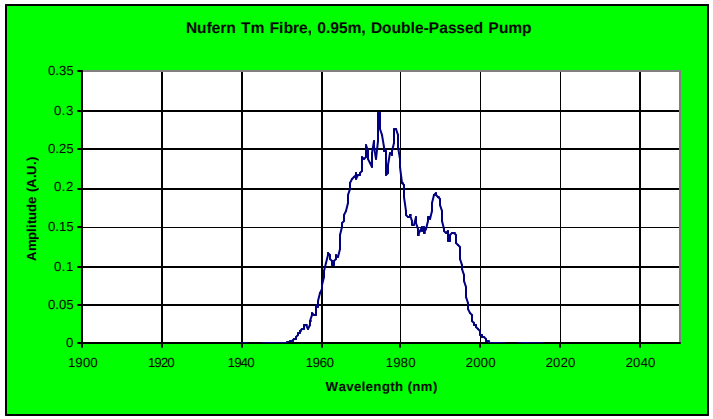


Tm-doped fiber laser:
40W CW pumped at 793nm

Australian Government
Department of Defence
Defence Science and
Technology Organisation

DATA Courtesy G. Frith, DSTO



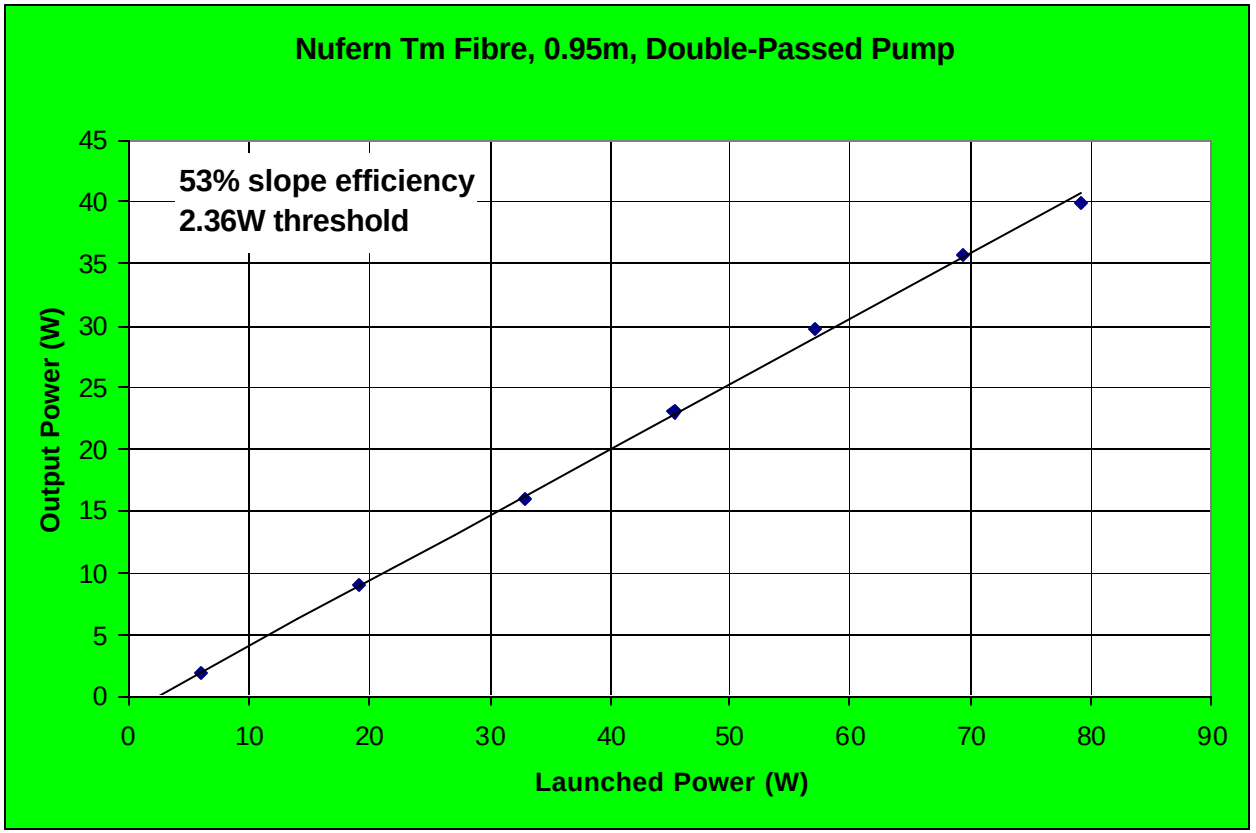


- High efficiency ~53% pump conversion
  - Lasing around ~1970nm pump at 793nm
  - Silica glass composition is optimised for high efficiency
    - Making use of Tm-ion cross relaxation process

Tm-doped fiber laser: ~40W output and 53% slope efficiency

Australian Government
Department of Defence
Defence Science and Technology Organisation

Data Courtesy G. Frith, DSTO



Conclusion

- LMA fiber technology is now well established
  - Various fibers optimized for different applications
    - pulsed, CW, PM, etc
  - Repeatable fiber manufacturing
    - gives customers confidence to build products around the technology and move fiber lasers from R&D projects into manufacturing
  - Standard LMA fiber designs have encouraged development of LMA components (gratings, couplers, etc)
- Standard LMA modules being introduced based on these components

Acknowledgments

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