High-efficiency 100W level monolithic fibre devices operating at 2µm

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21st June , 2007

Motivation

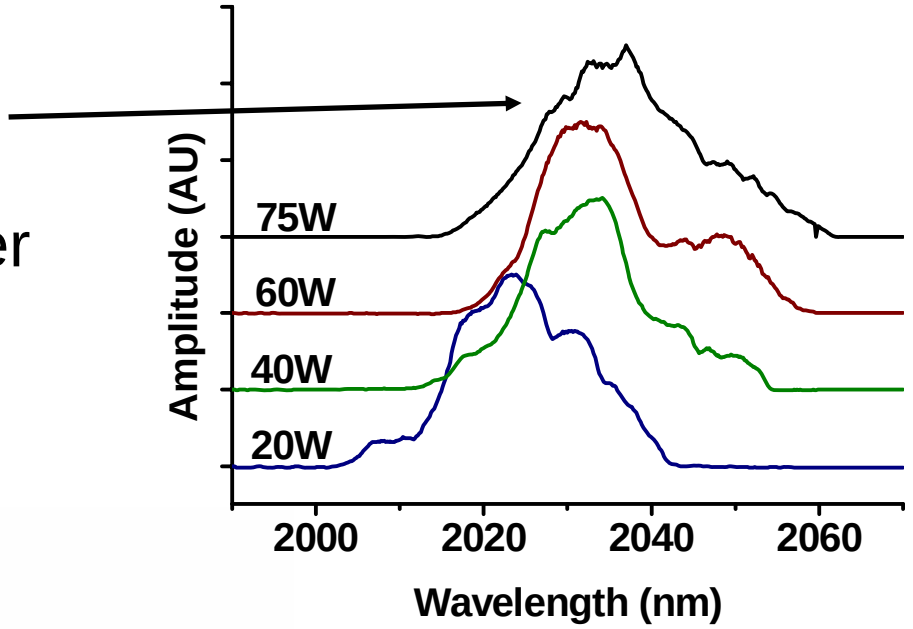
- 790nm pumped 2µm fibre devices achieve higher efficiency than current commercially available systems
  - Commercially available systems that use 9xx-nm diodes typically exhibit E-O efficiencies of 5 ~ 10%

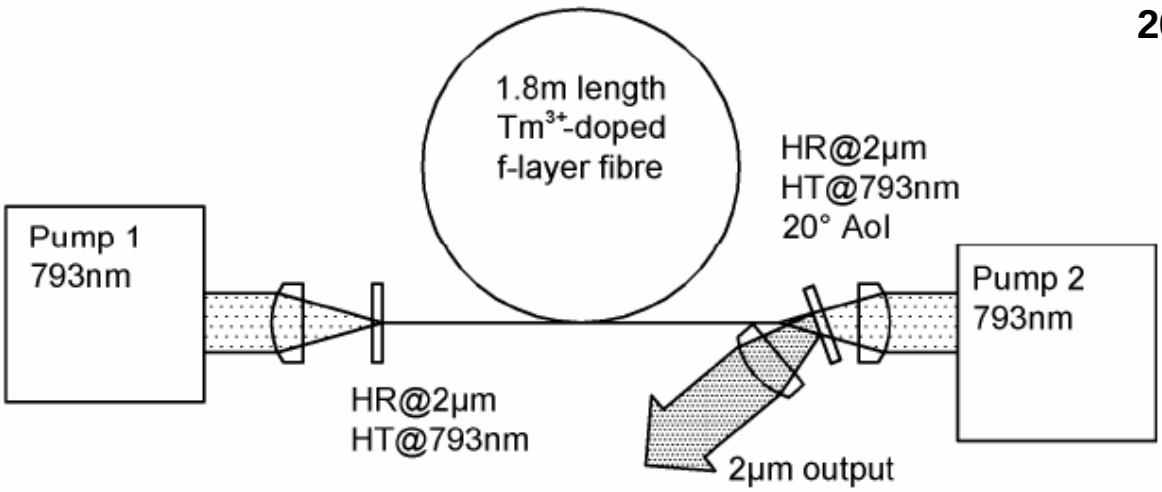
- For most applications it is attractive to improve this efficiency
  - To reduce the cooling or overall electrical requirements for the system
  - To reduce the number and cost of the pump diodes

- Recent research in Tm-doped fibres has shown direct pumping at ~790nm can produce >65% slope efficiency through optimising the cross relaxation of excited Tm-ions
  - Most of this research however has not yet progressed beyond free space laser cavities

Previous Research on high efficiency Tm-fiber lasers

~100W output power but the lasing wavelength is not fixed (depends on pump power, fiber length, etc). Output was also significantly multimode.

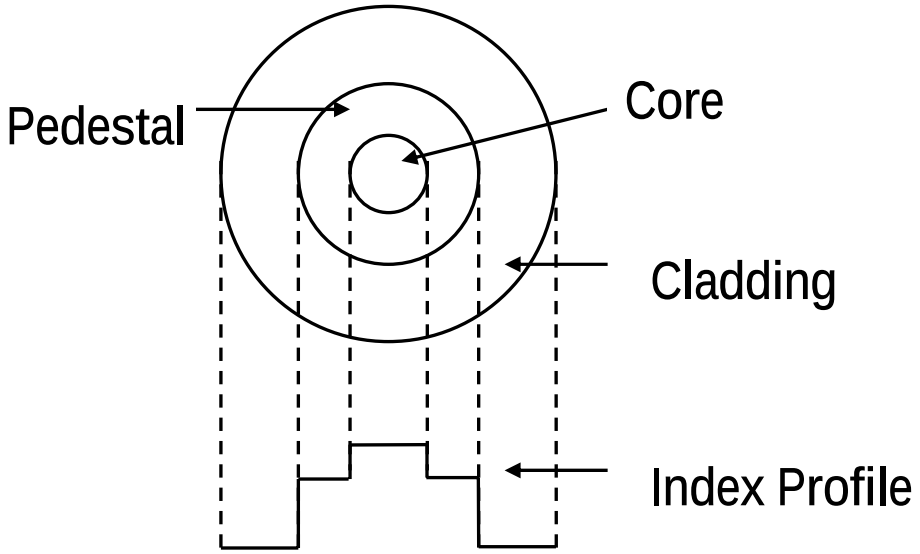


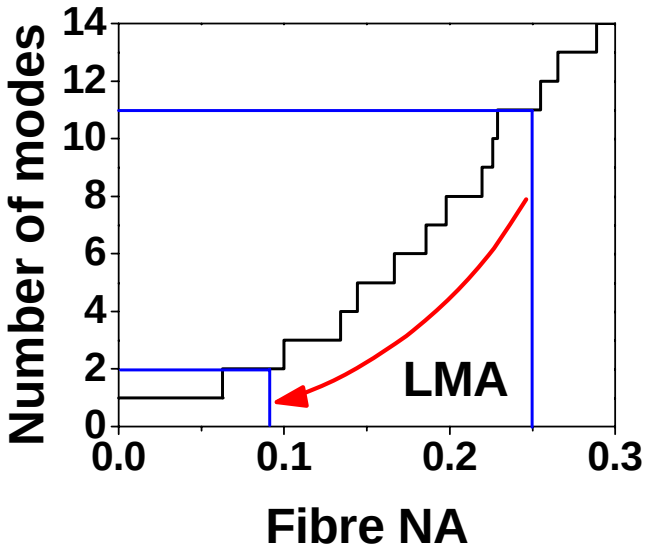


Typical free space pumping of laser and broadband dielectric mirror based cavity (G. Frith *et al*, SPIE LASE 2006)

Latest generation high efficiency Tm-fibres

- Optimised composition for slope efficiencies exceeding 65%
- Using the pedestal concept to lower the effective core NA from 0.25 to 0.08 resulting in robust single mode operation
- Panda stress rods may be inserted for PM operation
- Powers approaching 300W have now been demonstrated from our fibres. (Slobodtchikov *et al*, ASSP post deadline 2007)





Monolithic fibre laser cavity

- Fibre-coupled pump source directly spliced to laser cavity 200W @ 793nm from 400/480µm 0.22NA
- FBG high reflector (~-20dB) at 2050nm spliced to 5m of 25/400 LMA Tm-doped fiber
- Output feedback was Fresnel reflection from cleaved fibre facet only
- Low reflectivity O/Cs are currently being developed

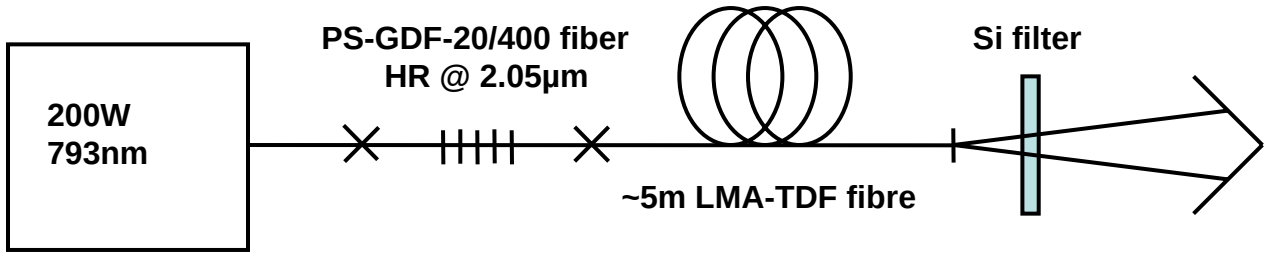
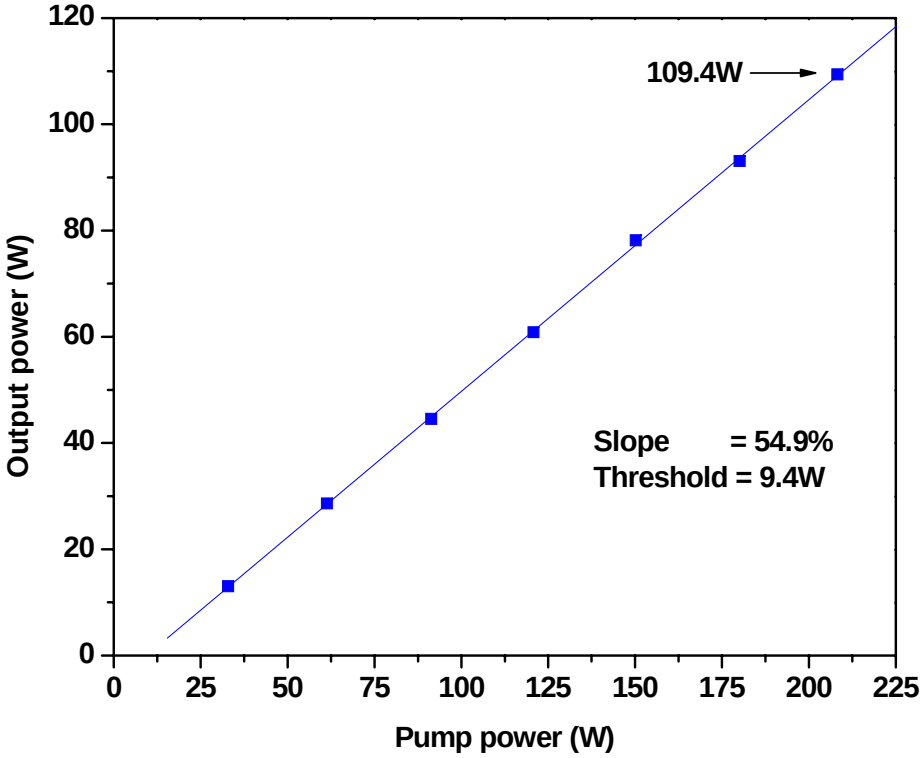
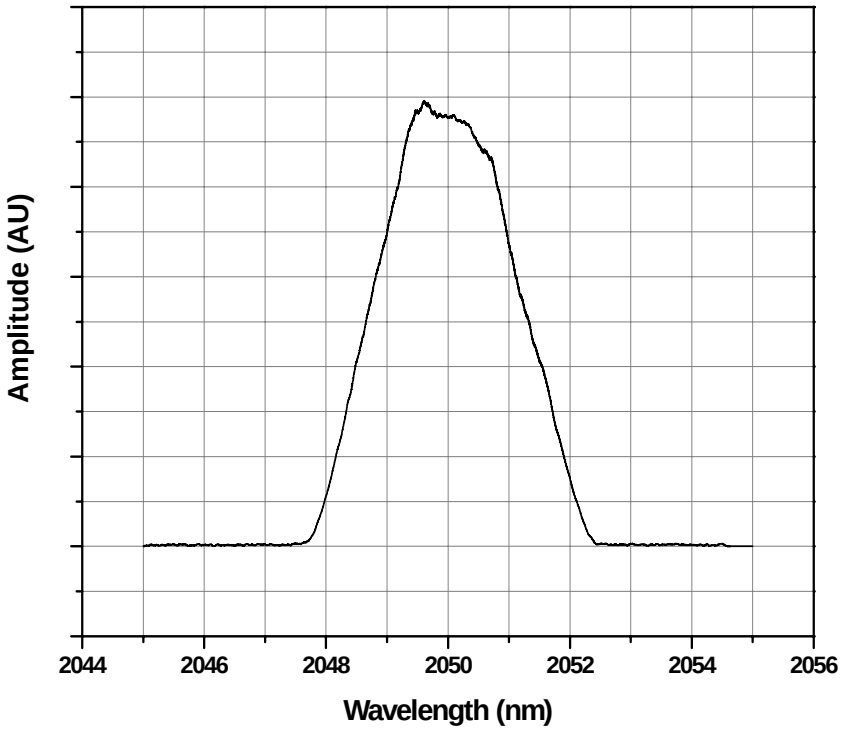


Figure 1: Schematic of FBG based laser operating at 2µm

Results from the monolithic cavity

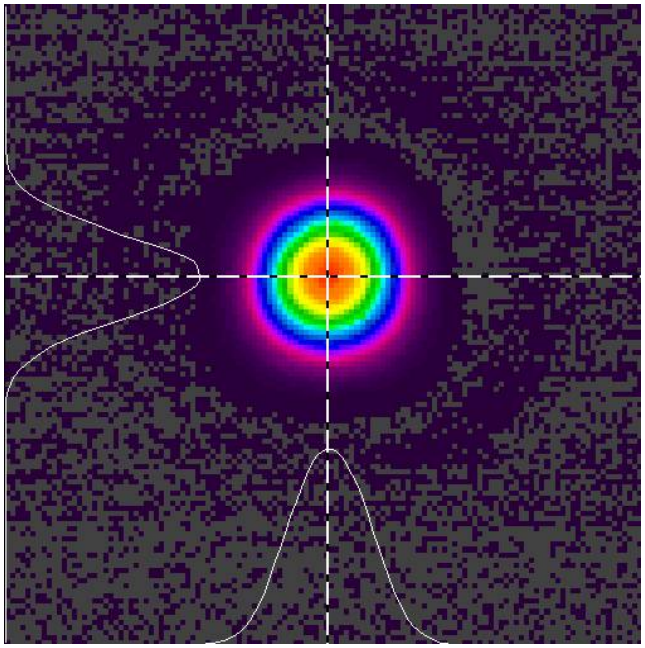
- ~110W output power at 2050nm (FWHM ~2.5nm)
- Slope efficiency ~55%
- Using 793nm bar based pump E-O efficiency = 17% at 110W
- No evidence of thermal rollover or instability

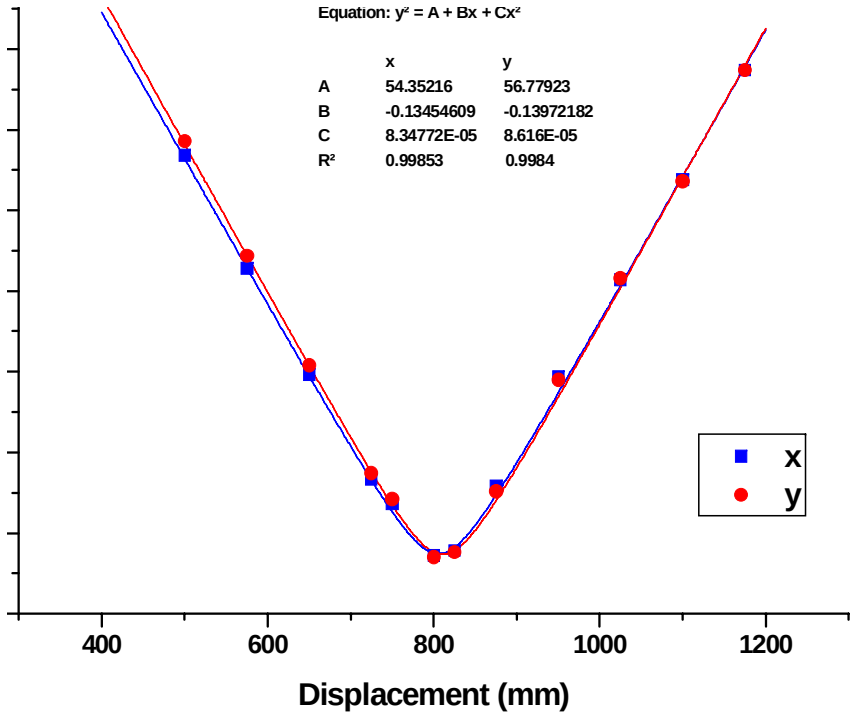




Results from the monolithic cavity

- Single spatial mode beam from the laser (V_{eff}= 2.61 @ 2.05µm)
- M^2 was calculated at 1.3 (non-optimised optics for the measurement)
- Fibre was coiled on Ø12cm mandrel for heat removal and mode control

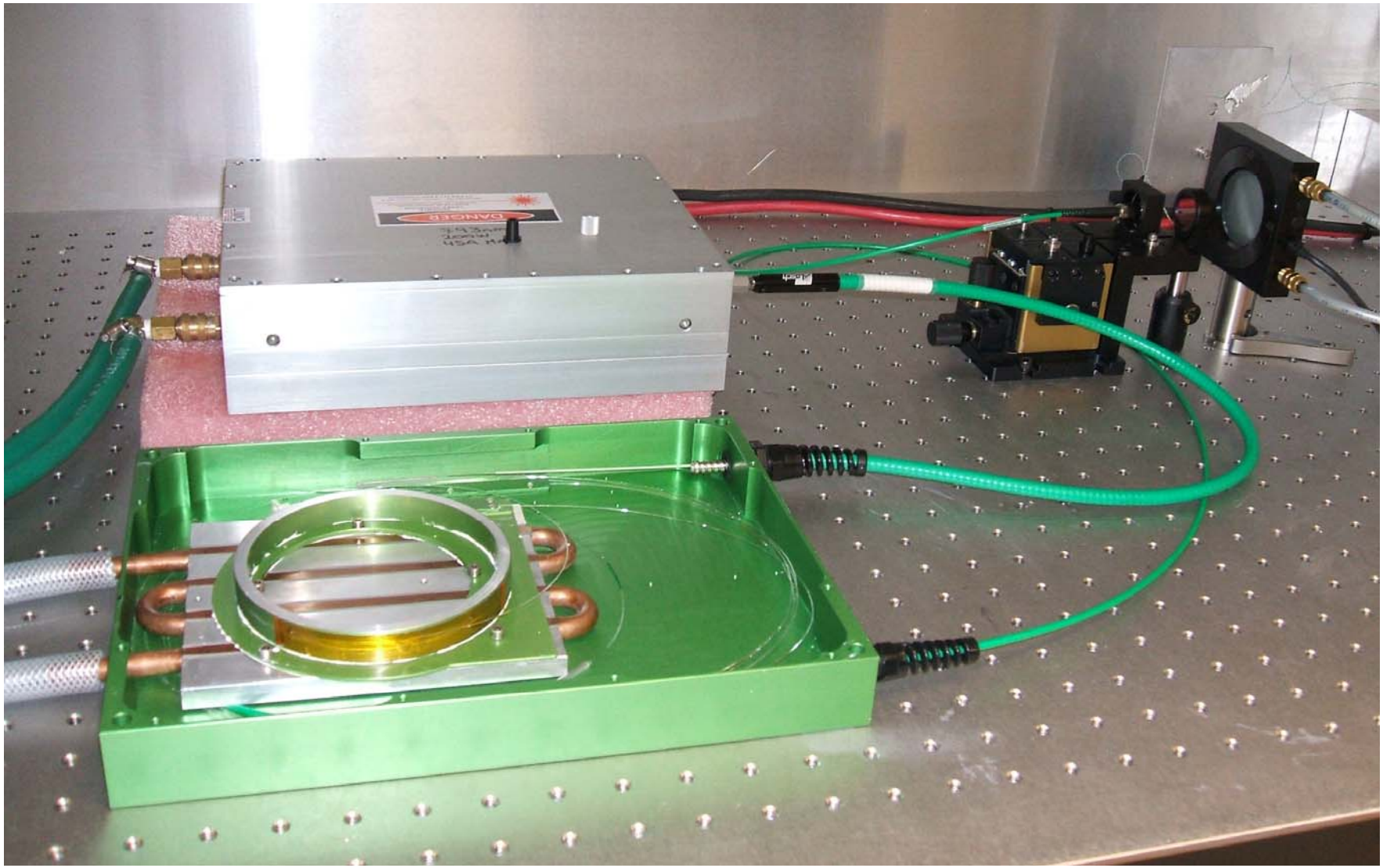




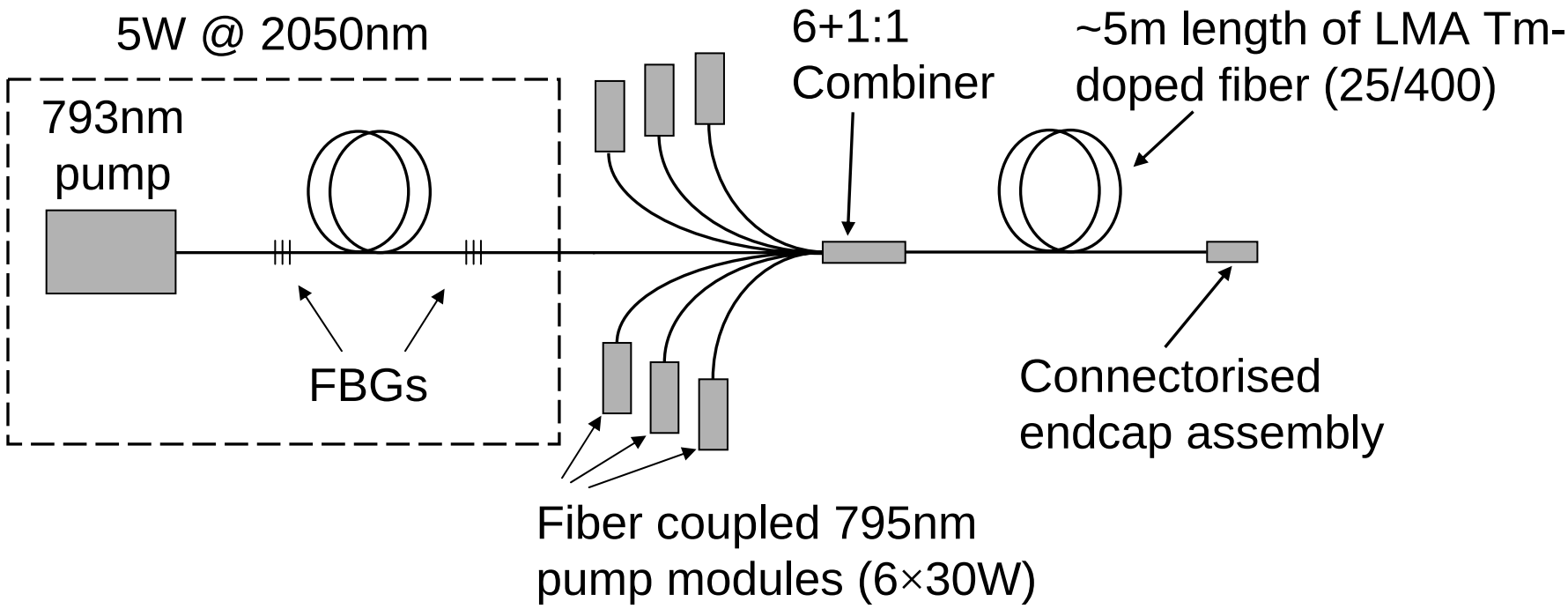
Complete system

- 294 × 217 × 34mm (a lot of free air)
- LD80 pump input connector
- FC/PC output connector
- Passively-cooled fibre mandrel
  - Current system used water-cooled cold plate
  - Design easily adapted to TEC / heatsink cooling

Complete system

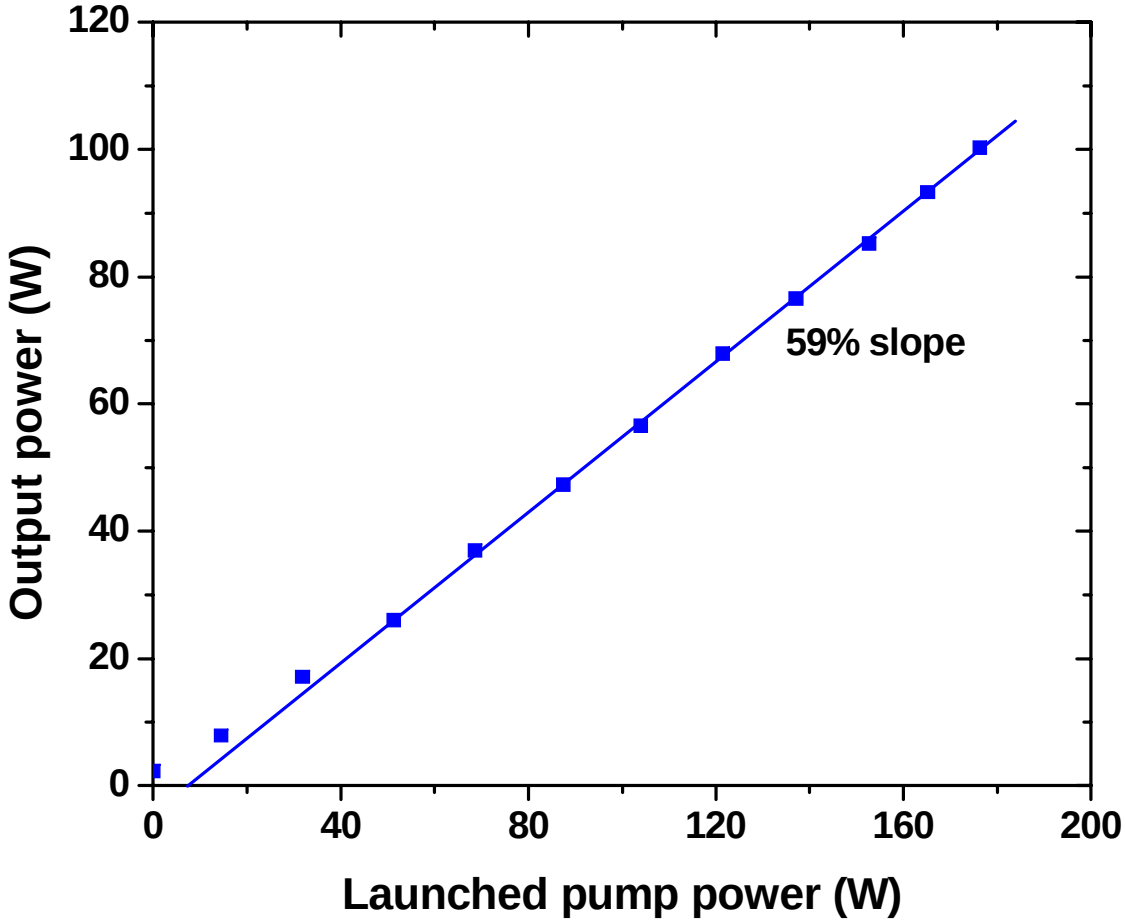


25/400µm Tm Amplifier



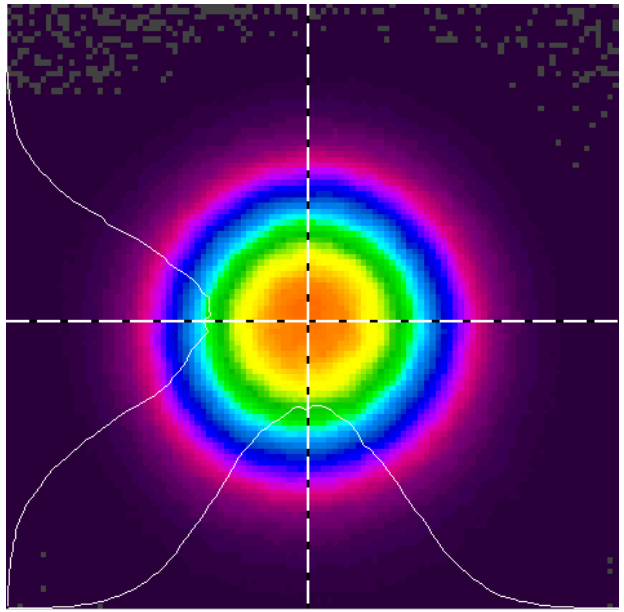
Amplifier performance

- 5W seed @ 2050nm
- 176W coupled pump
- 100.3W output
- →13dB gain

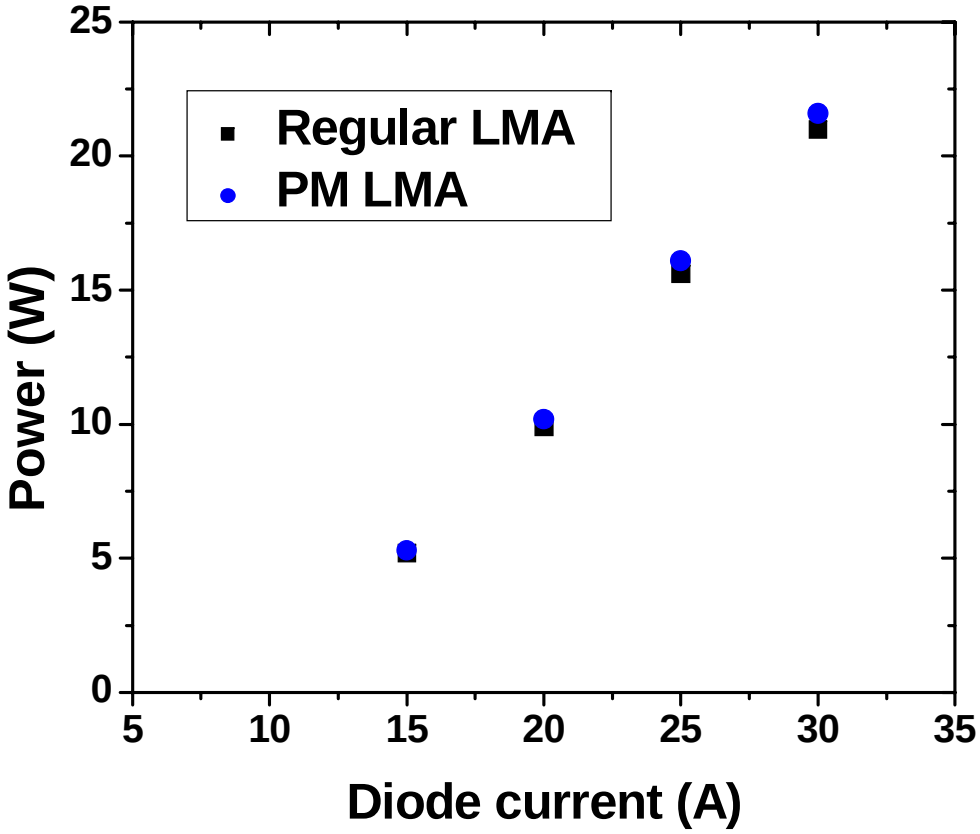


PLMA-TDF-25/400 performance

- Identical (if not slightly higher) performance to regular LMA
- Birefringence ~2.5×10^{-4}
- Matching PM combiners have also been developed



FF beam image from PLMA-TDF-25/400 amp



Conclusions

- We have presented two examples of robust 2µm monolithic fibre devices devices operating at ~100W level.
- Absence of thermal roll-over indicated pump-power limited performance.
- 790nm pumped Tm devices achieve higher E-O efficiencies than contemporary systems incorporating Yb pumped Tm, Er:Yb pumped Tm, Yb sensitised Tm etc.
- Measured E-O efficiency of the laser was ~17% using bar diodes. With higher efficiency pumps, this would easily exceed 20%. This is attractive for applications where cooling and electrical power requirements are restricted.
- 1908nm & 1940nm presently under development (Ho:YAG & Ho:YLF pumping)