An astrophotonic approach to near-IR diverse field spectroscopy

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Talk outline

- Astrophotonic near-IR diverse field spectroscopy.
- Astrophotonic OH-line suppression.
- Multimode-to-single mode conversion.
  (The Photonic Lantern)
- The Photonic Integrated Multimode Micro-Spectrograph (PIMMS) instrument concept.

- Mass-production of Photonic Lantern Technologies.
- Multicore Fibres.
- Ultrafast laser inscription.

- Summary / Conclusions.

Astrophotonic approach to near-IR diverse field spectroscopy

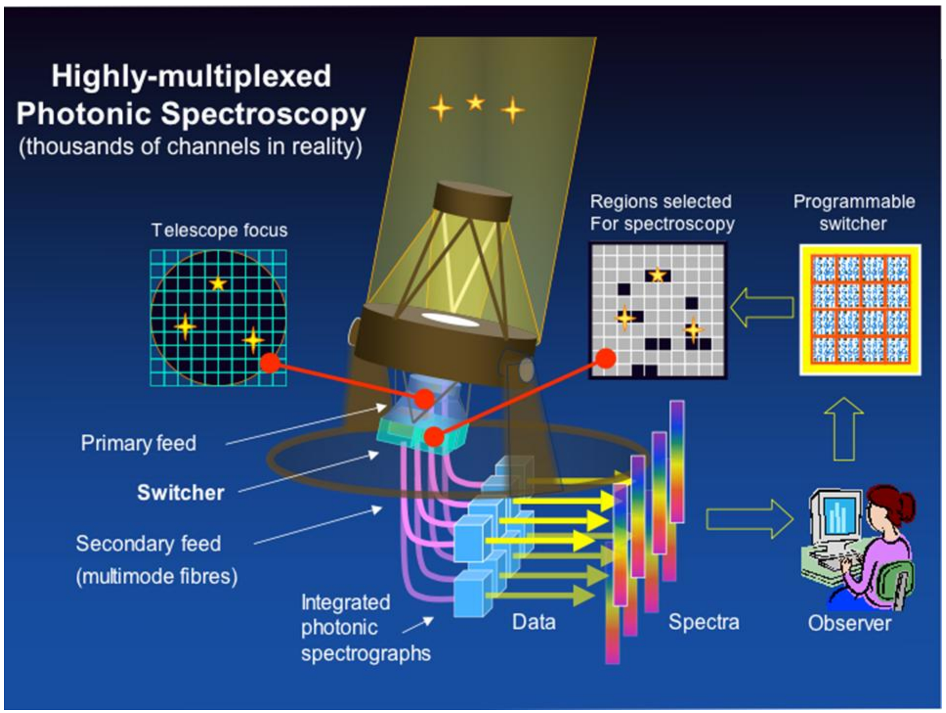
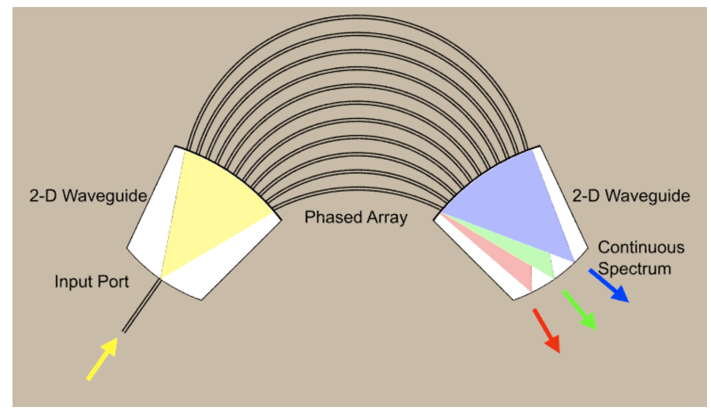


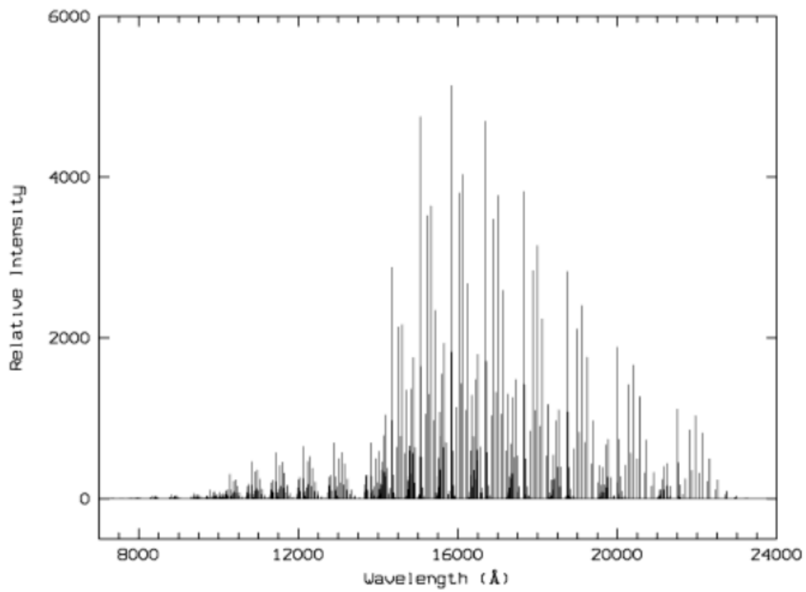
Image courtesy of J. Allington-Smith (CfAI - U. of Durham)

Instruments without optics: an integrated photonic spectrograph

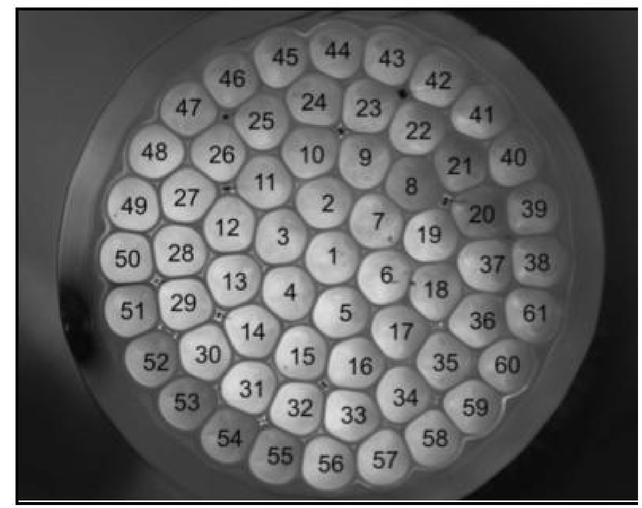
J. Bland-Hawthorn[a], A. Horton
Anglo-Australian Observatory, 167 Vimiera Rd, Eastwood, NSW 2122, Australia



Astrophotonic approach to near-IR diverse field spectroscopy

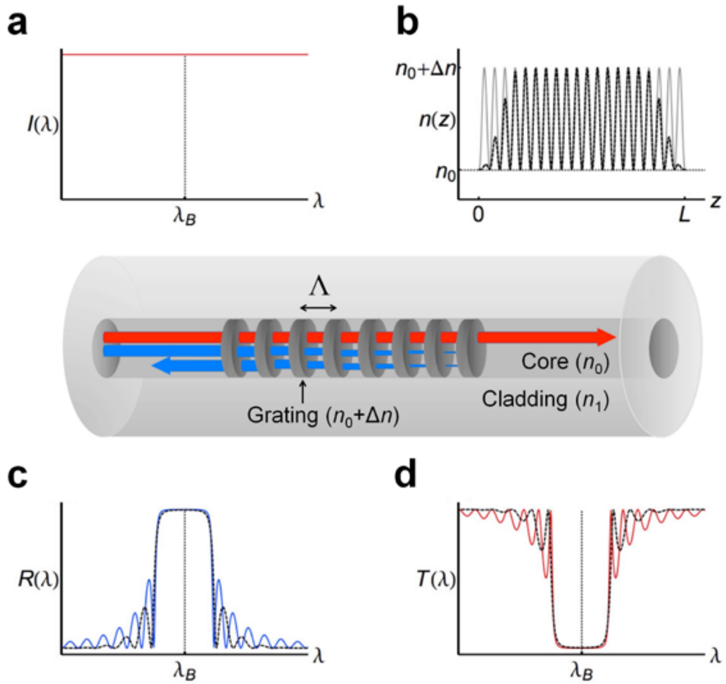


Synthetic spectrum of the night sky OH-emission
P. Rousselot et al,
Astron. & Astrophys. **354**, 1134 (2000)

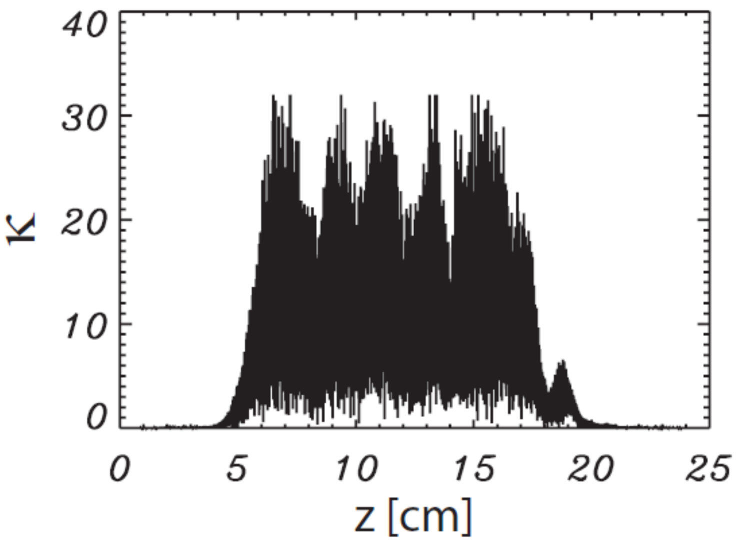


Hexabundle integral field units
J. Bland-Hawthorn et al,
Opt. Express **19**, 2649 (2011)

Astrophotonic OH-line suppression



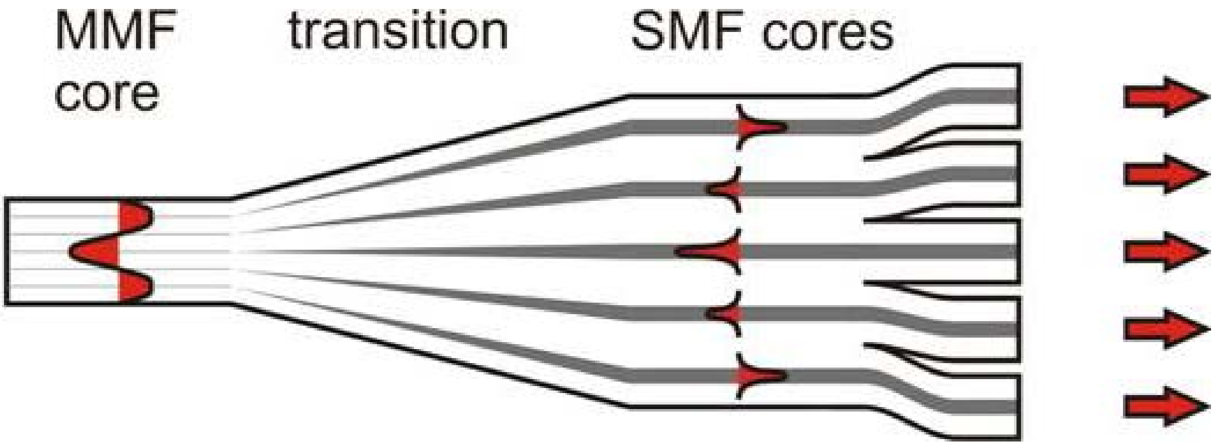
Operation of a fibre Bragg-grating
J. Bland-Hawthorn et al,
Nature Commun. **2**, 581 (2011)



FBG design for a ≈ 150 suppression channel filter
A. Buryak et al,
Opt. Express **17**, 1995 (2009)

Multimode-to-single mode conversion - The photonic lantern

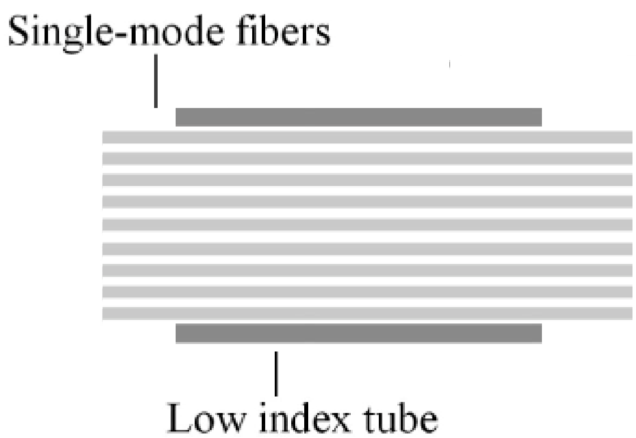
•Couple light from one MMF to several SMF cores along a gradual taper transition

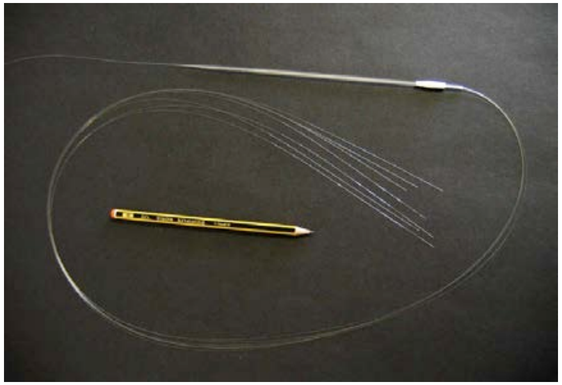


S. G Leon-Saval et al, Opt. Lett. 30, 2545 (2005)

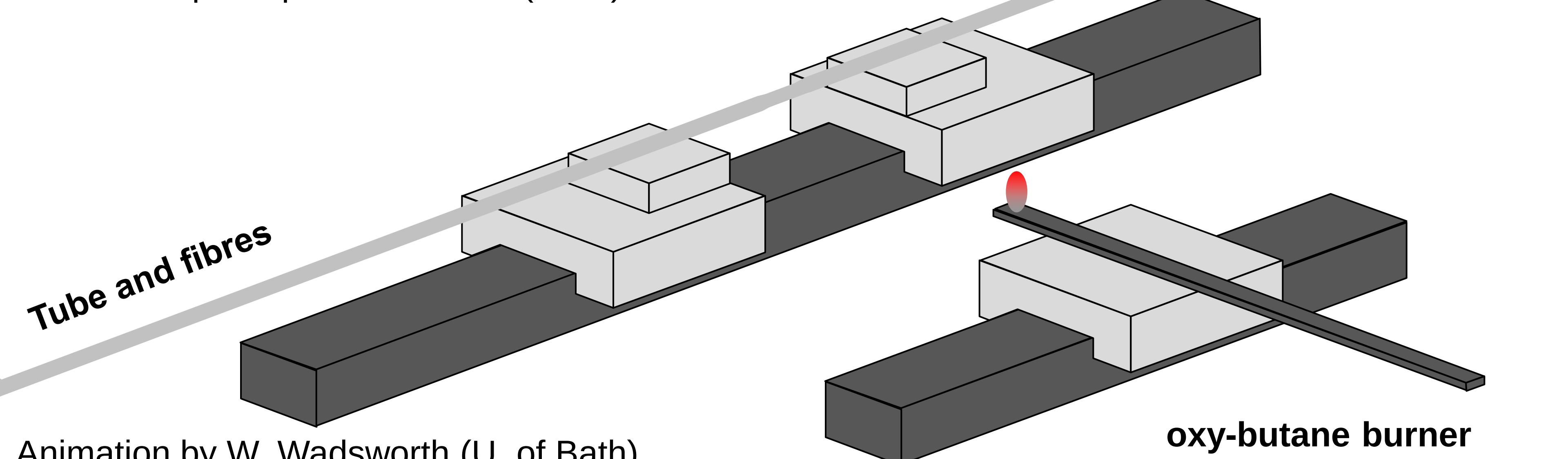
•Low loss: let N (number of single modes) = M (number of MMF modes)
$\Rightarrow$ conserve no. modes / entropy / brightness / etendue couple light from one MMF to several SMF cores along a gradual taper transition

The photonic lantern fabrication



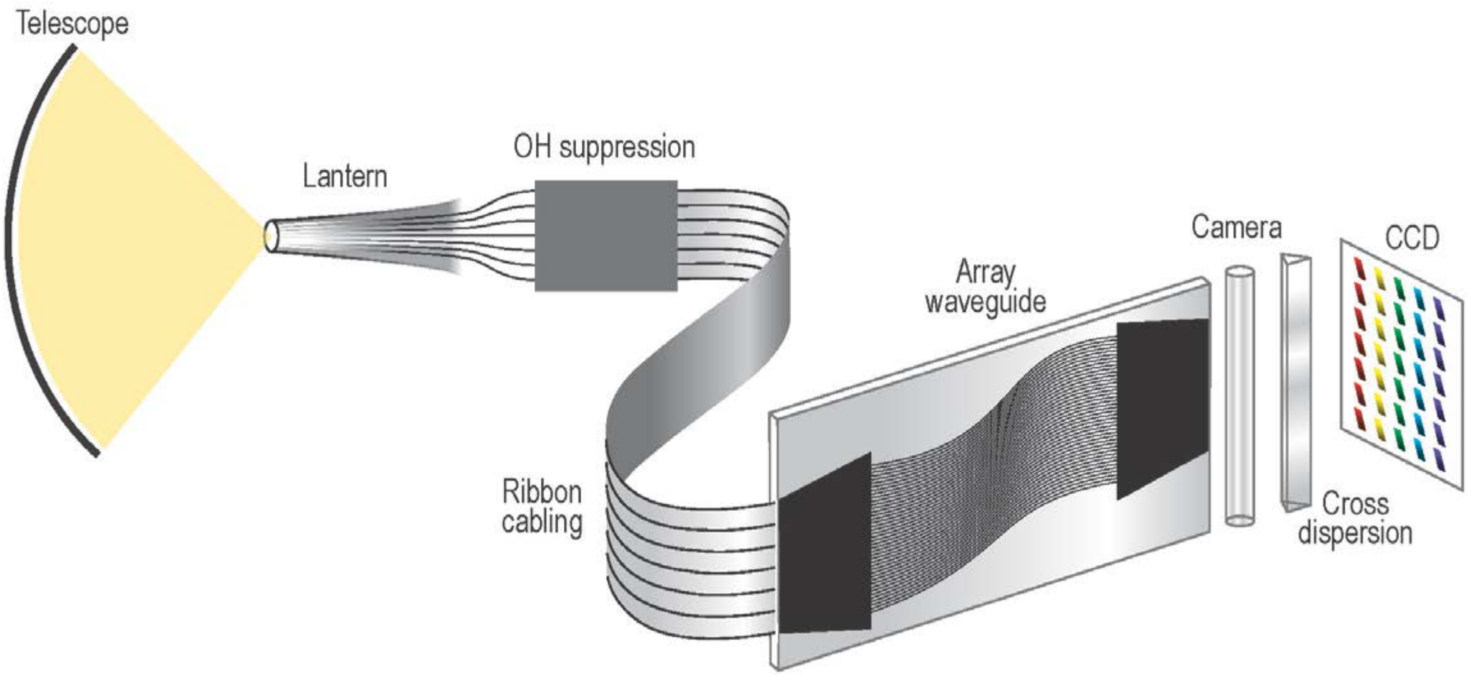


D. Noordegraaf et al,
Opt. Express 18, 4673 (2010)



Animation by W. Wadsworth (U. of Bath)

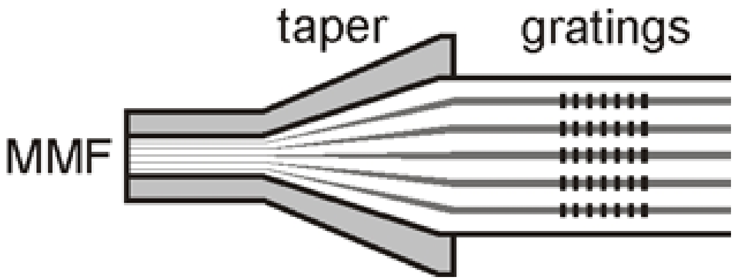
The photonic integrated multimode micro-spectrograph (PIMMS)



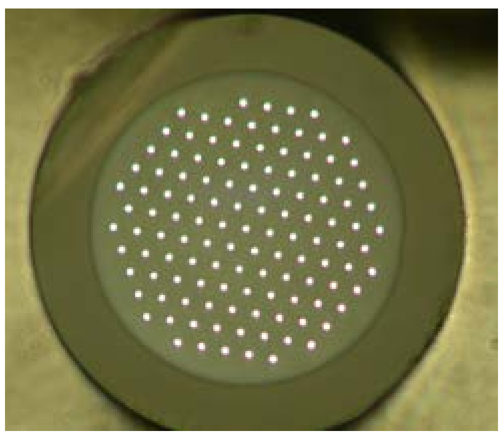
The PIMMS instrument concept

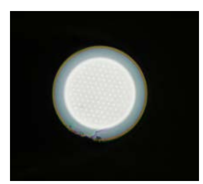
J. Bland-Hawthorn et al,
Proc. SPIE 7735, 77350N (2010)

Mass production of photonic lanterns

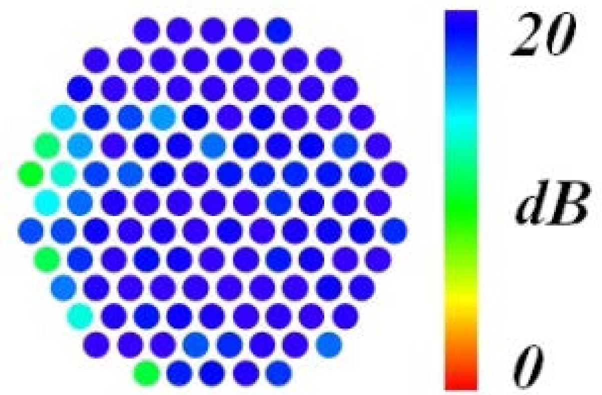


S. G. Leon-Saval et al,
Opt. Lett. 30, 2545 (2005)

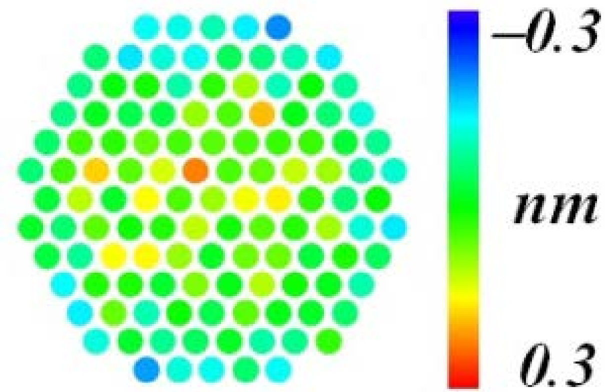




Transition loss of ≈ 0.5 dB at λ = 1550 nm.
T. A. Birks et al, Frontiers in Optics 2010, paper FTuU1



(a)

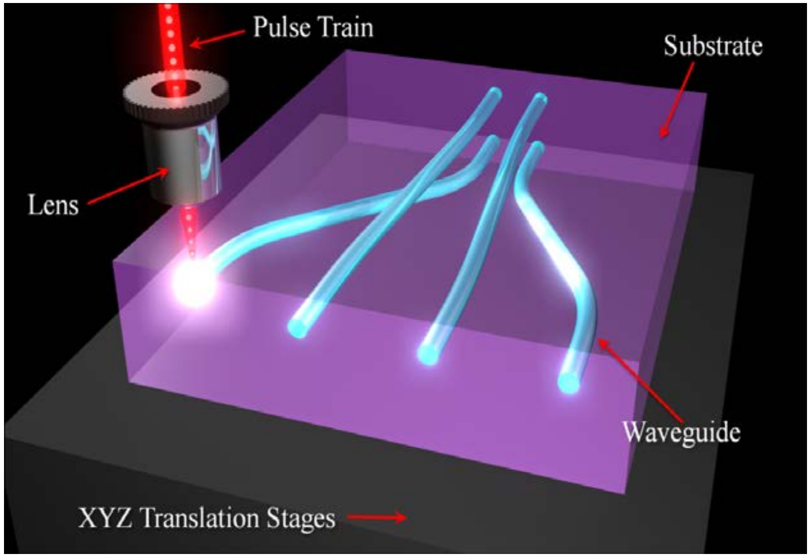


(b)

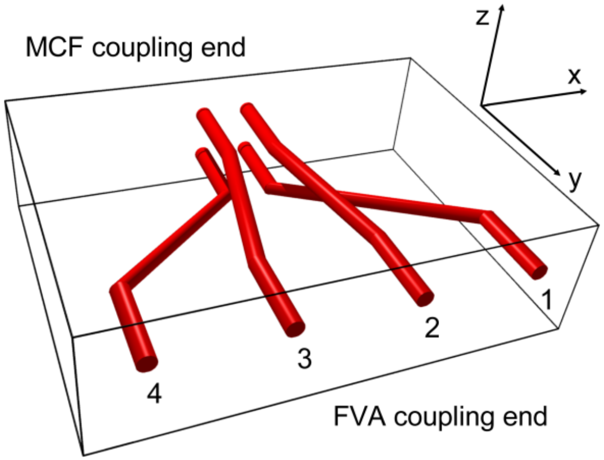
(a) Grating strength in each MCF core
(b) Grating centre wavelength

For more information, see T. A. Birks et al, "“Photonic lantern” spectral filters in multi-core fibre" Accepted for publication in *Opt. Express* May 2012

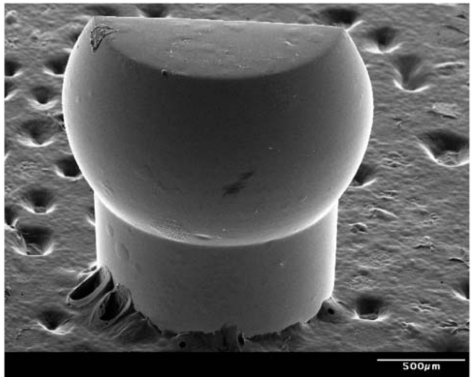
Ultrafast laser inscription (ULI)



Cartoon of ULI process



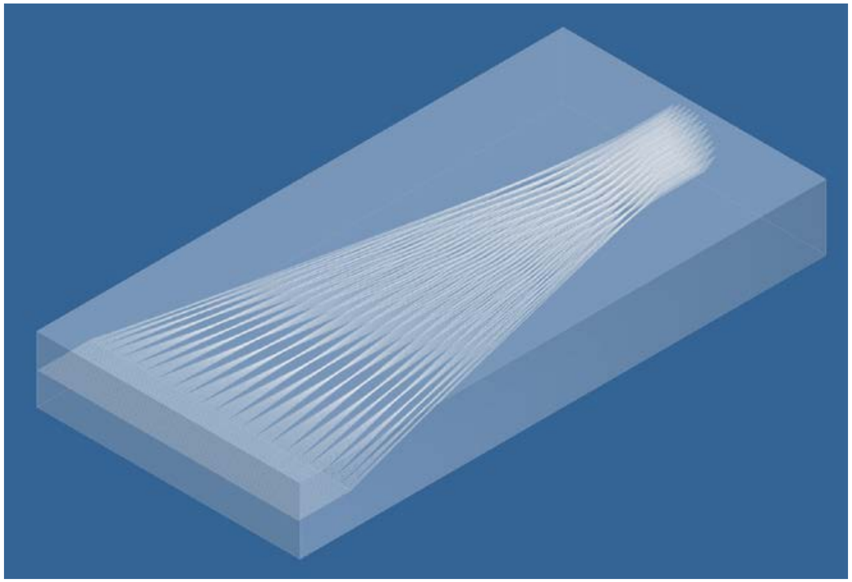
R. R. Thomson et al, Opt. Express 15, 11691 (2007)



Y. Cheng et al, Appl. Phys. A 85, 11 (2006)

- Unique fabrication capabilities:
- 3D optical waveguides.
- Micro-optics, -mechanics and -fluidics.
- ULI is material flexible.
- ULI is a direct-write technology.

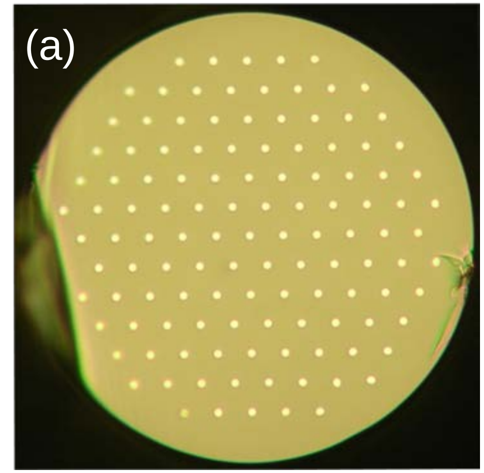
3D interconnects via ULI

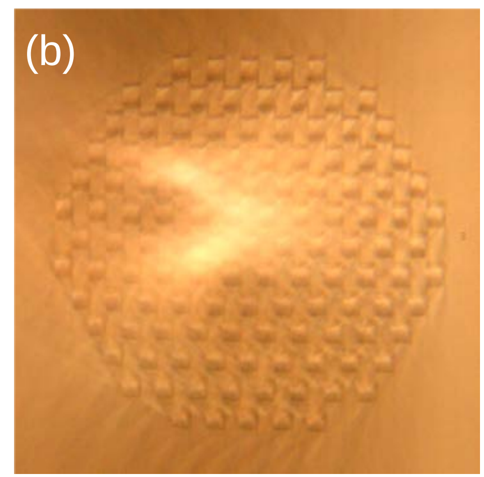


Conceptual diagram of the 3D fan-out device

- Insertion losses for individual cores ≈ 1.5 dB
- Best total throughput so far ≈ -7 dB

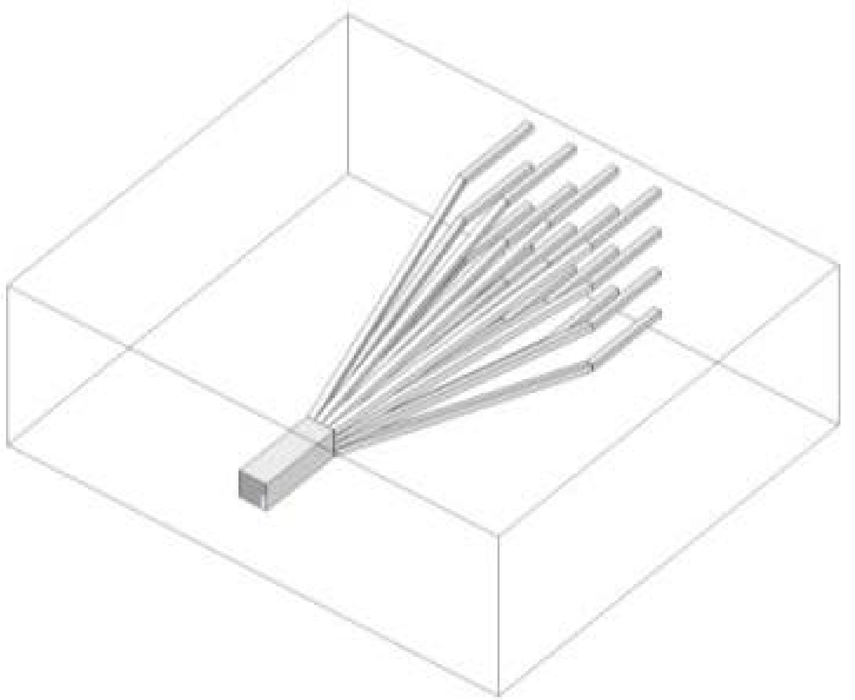
For more info, see: R. R. Thomson et al, “Ultrafast laser inscription of a 121 waveguide fan-out for astrophotonics" Accepted for publication in *Opt. Lett.* (May 2012)



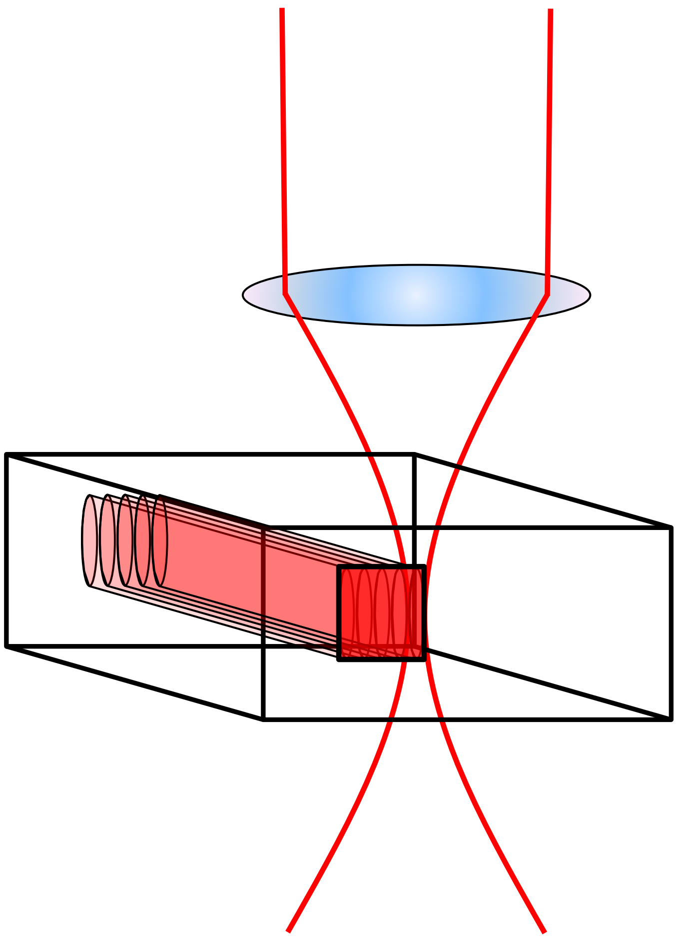


Optical micrograph of (a) the 120 core MCF and (b) the MCF coupling end of the 3D fan-out

Integrated photonic lanterns via ULI

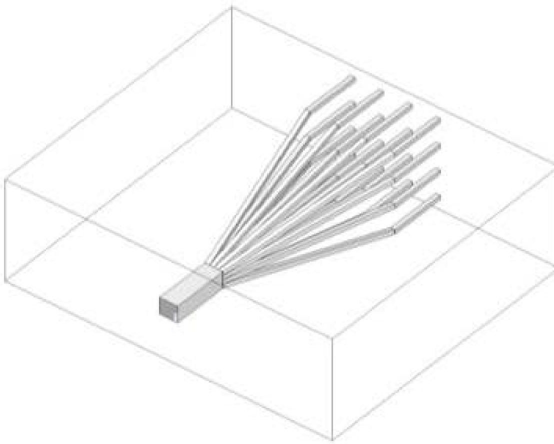


Cartoon of the proposed integrated photonic lantern



Waveguide shaping using the multiscan technique

Integrated photonic lanterns via ULI



Cartoon of the proposed integrated photonic lantern

Ultrafast laser inscription of an integrated photonic lantern

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[2]*Department of Physics, University of Bath, Claverton Down, Bath, BA2 7AY, UK*
[3]*Institute of Photonics and Optical Science, School of Physics, University of Sydney, NSW 2006, Australia*
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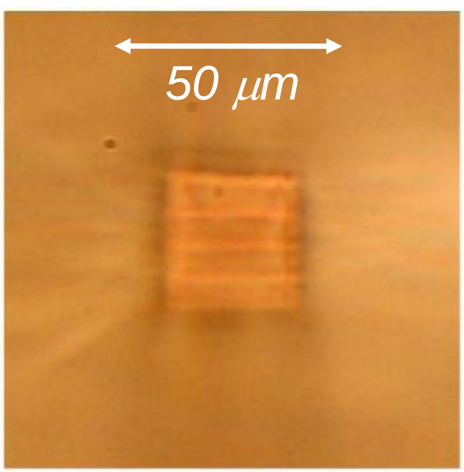
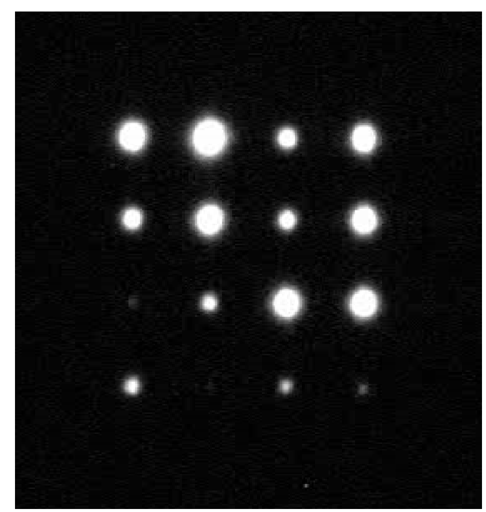
- Multimode-to-single modes conversion loss ≈ 2.0 dB
- We attribute < 0.5 dB to mode coupling losses



μ-graph of multimode waveguide



Near field video of 1.55 μm single modes

Summary / Conclusions

- Astronomy is now driving the development of entirely new photonic devices and concepts.
- Astrophotonic technologies have the potential to revolutionise near-IR astronomy.
- In the UK we have an opportunity to become leaders in astrophotonic technologies.

Acknowledgements

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- L. Labadie (U. of Köln)