Astrophotonics

Robert J. Harris (LSW, Universität Heidelberg)

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Talk outline

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What is Astrophotonics? (quick)

Why use Astrophotonics? (quick)

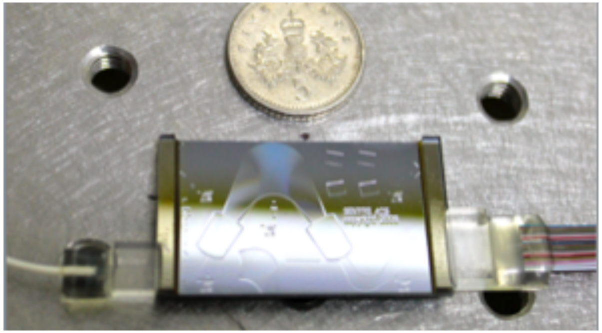
What technologies that are being developed?

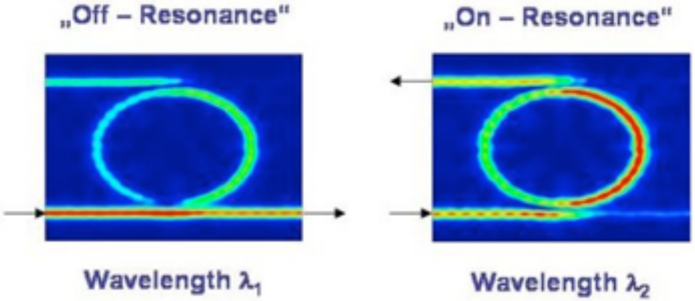
What is Astrophotonics?

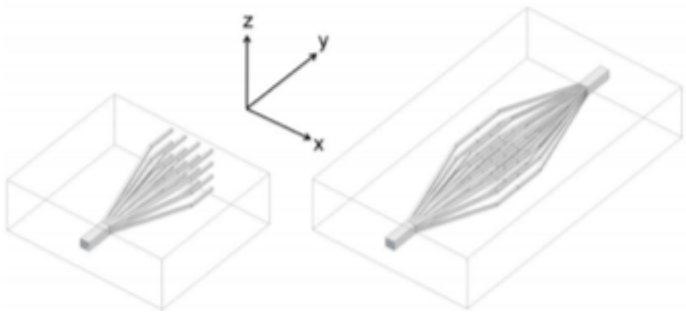
We already use it

Simply : The use of photonic technologies in astronomy (and vice versa)

It is very much a buzzword







So why use photonics in Astronomy?

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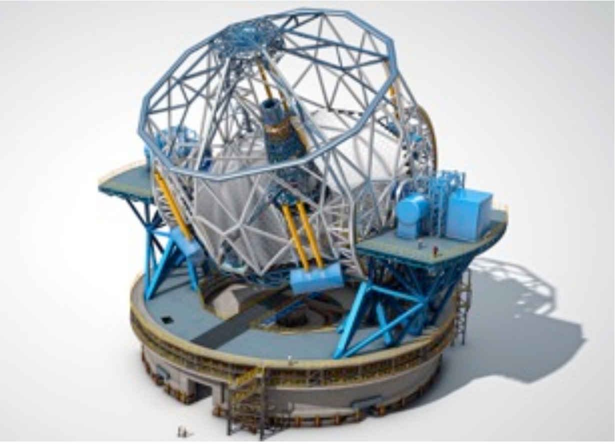
Instruments are getting bigger

For the ELT instruments will be around the size of a small apartment.

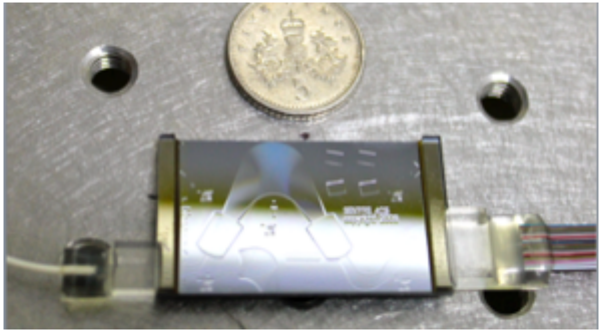
Can split the parts to make smaller more stable and add functionality.

This can be done using photonics e.g. cheap, small components.

This is not the solution to all problems



Credit : ESO



What are Photonic technologies capable of?

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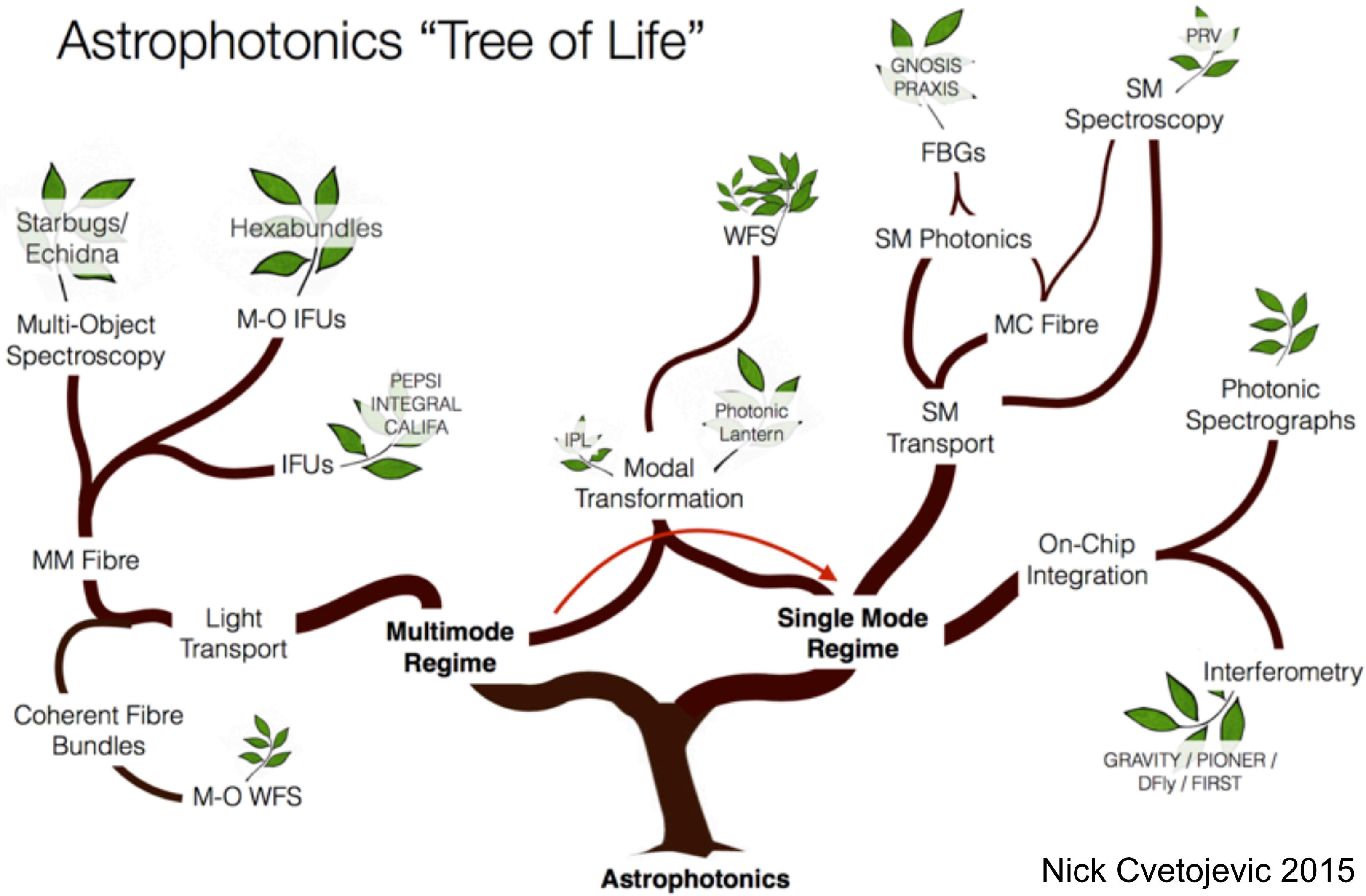
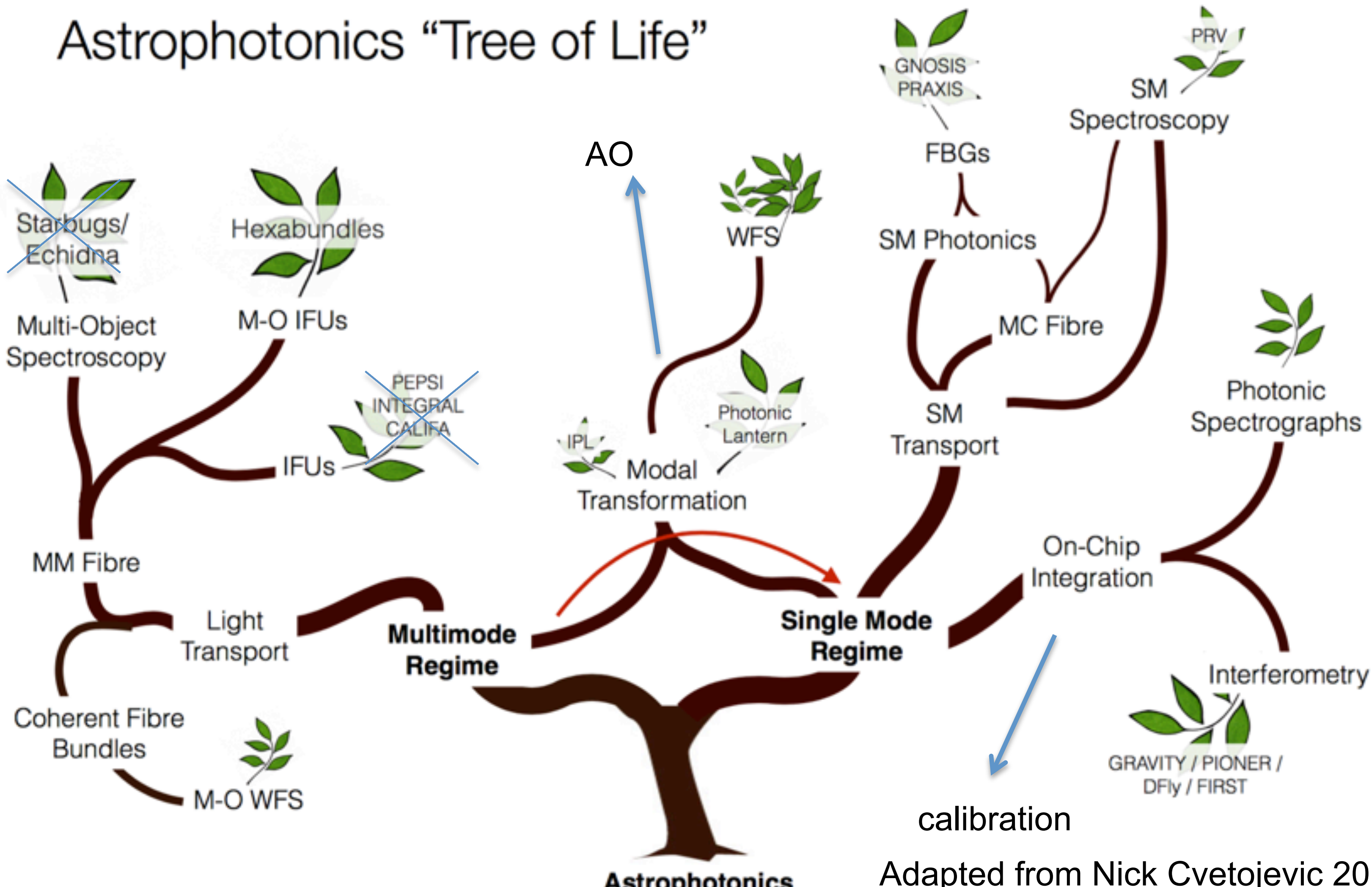


Nick Cvetojevic 2015

What is Astrophotonics



Adapted from Nick Cvetojevic 2015

The Regimes and mode transformation

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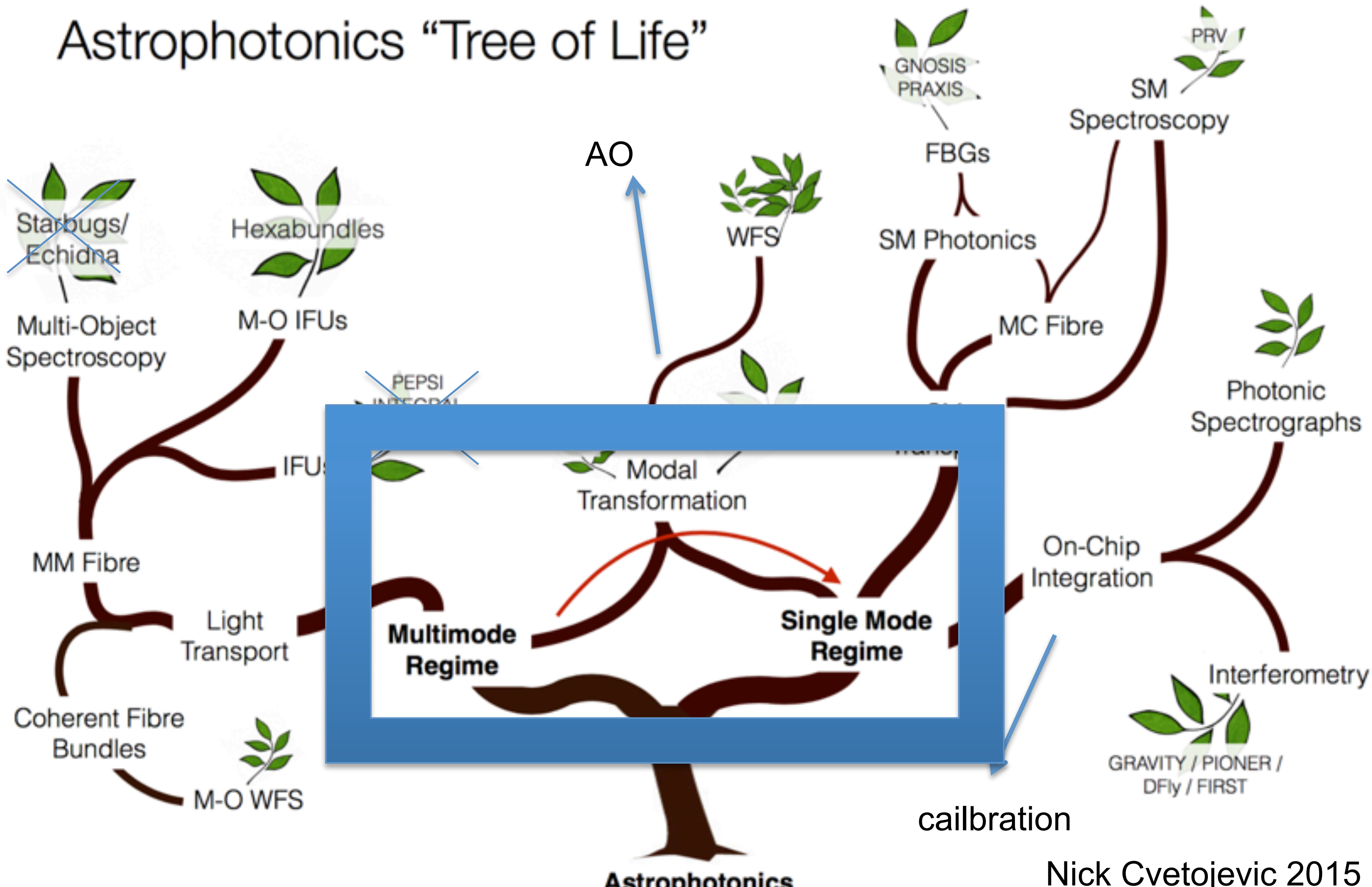

Modes and Telescopes

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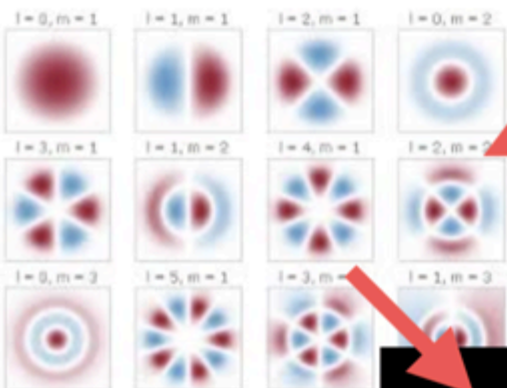
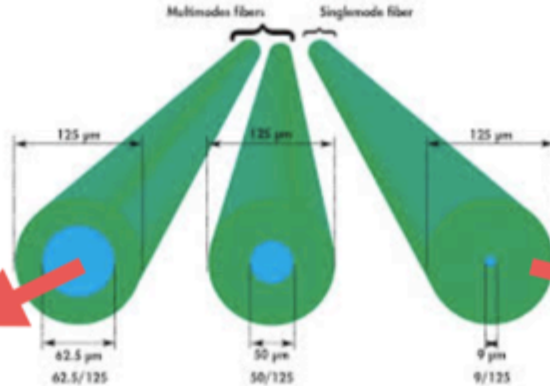
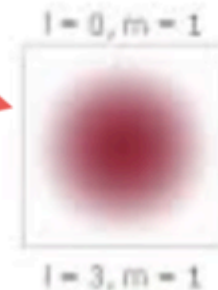
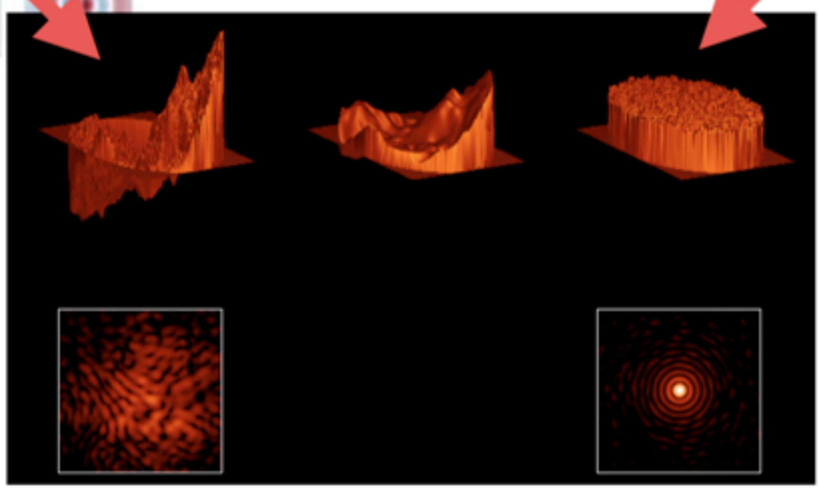
Multimode Fibre - Light Buckets
Easy* to inject light efficiently





Single Mode Fibre - Spatial Filter
Very difficult* to inject light efficiently

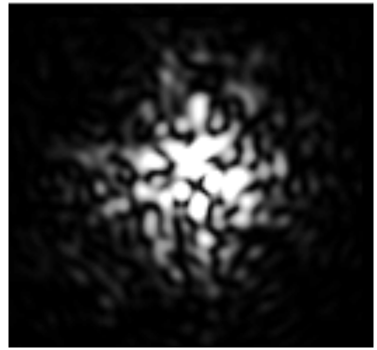


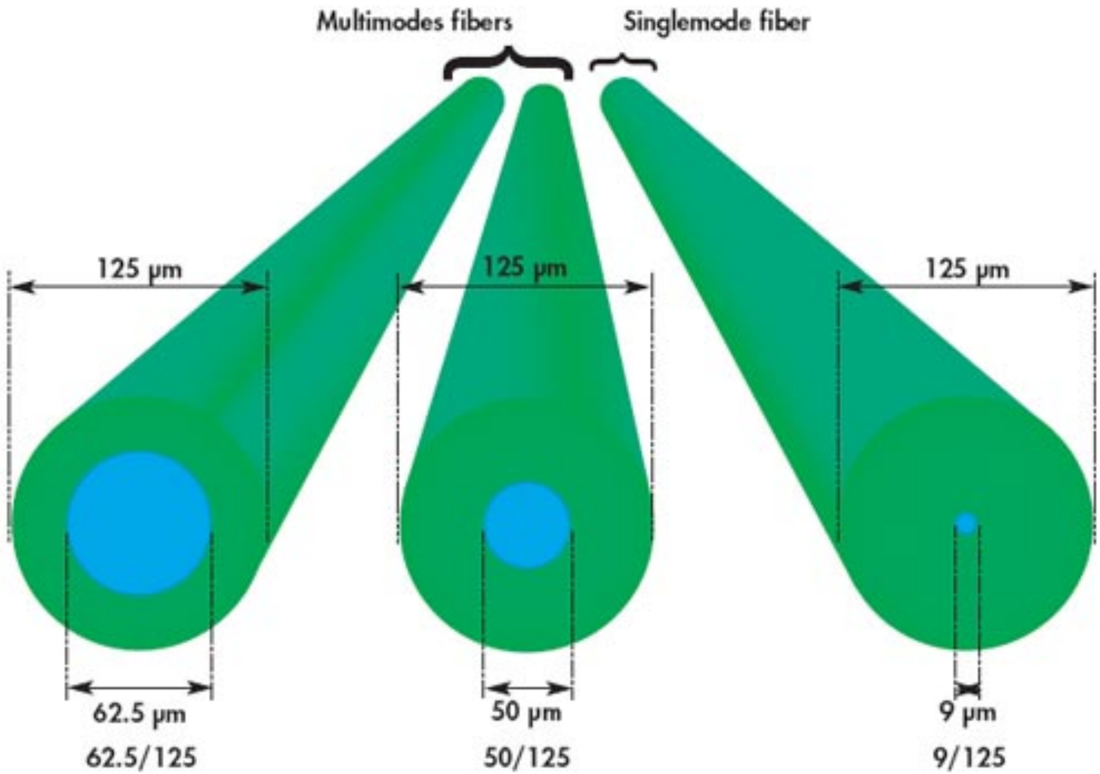


- V <2.4048
- Flat wavefront
- Gaussian intensity profile

Credit : Nick Cvetojevic

Modes and Telescopes
Seeing limit





~0%

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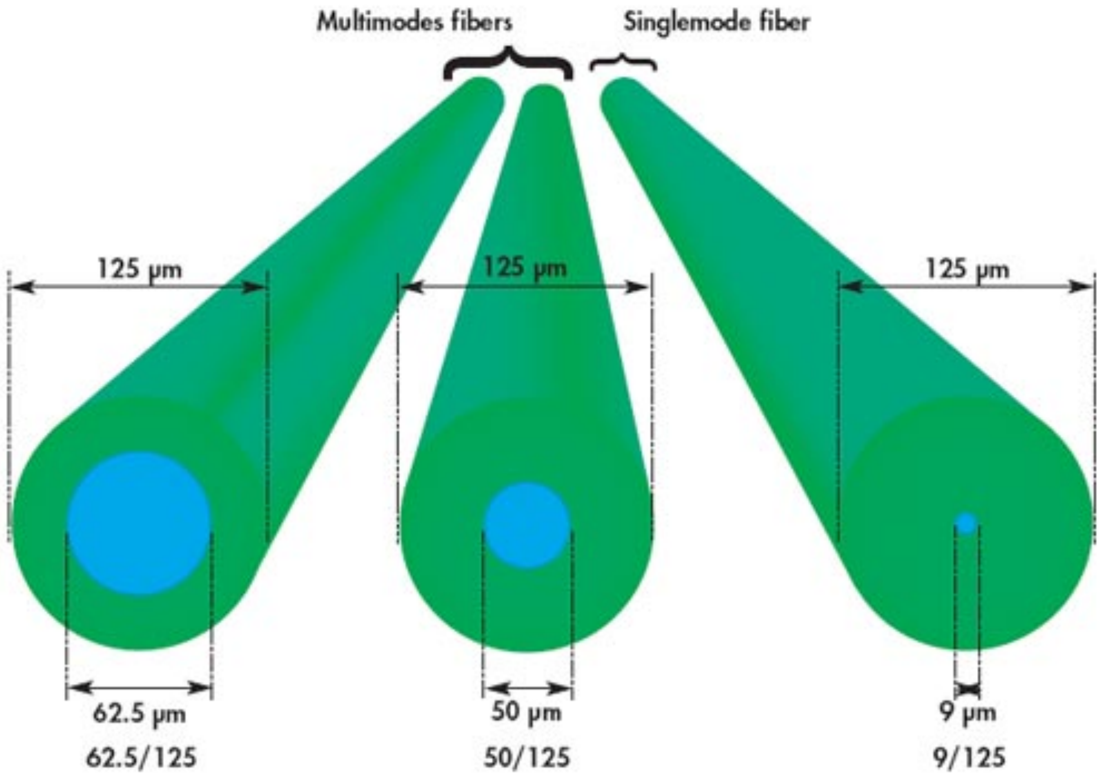
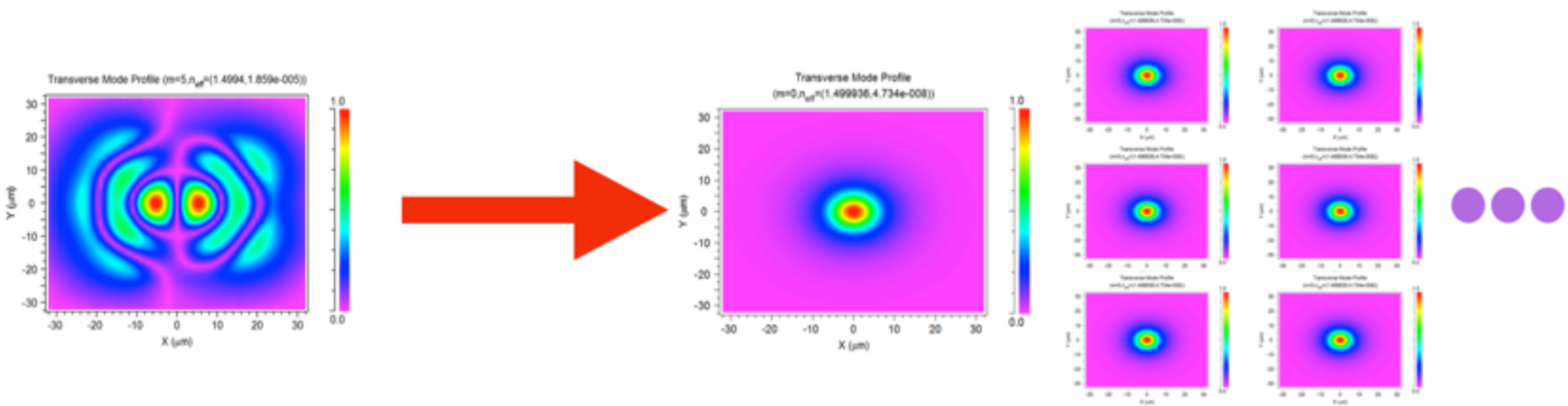
Modes and Telescopes
Diffraction limit



~80%

Can we convert between the two?



Credit : Nick Cvetojevic

Fibers

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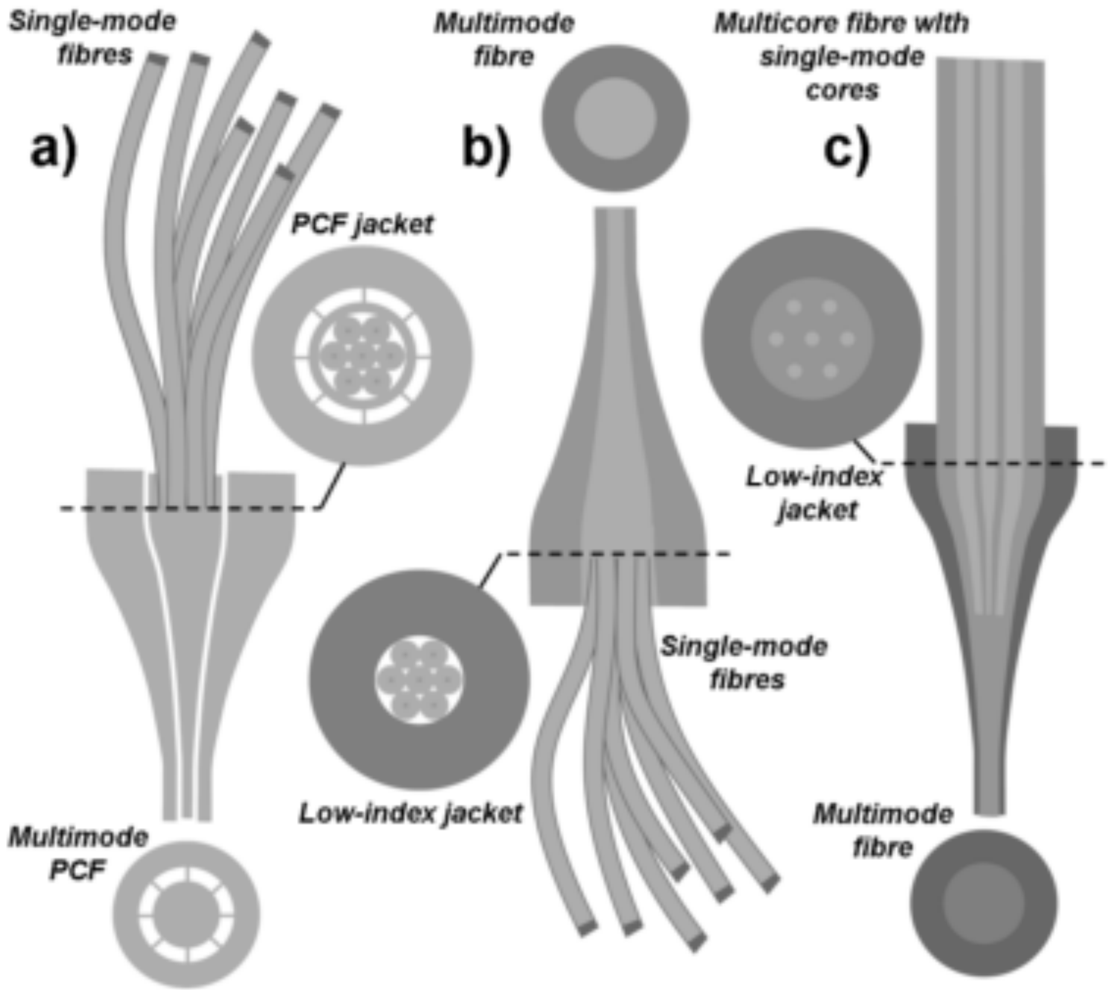

Multimode fiber devices with single-mode performance

S. G. Leon-Saval and T. A. Birks
Department of Physics, University of Bath, Claverton Down, Bath BA2 7AY, UK

J. Bland-Hawthorn
Anglo-Australian Observatory, P.O. Box 296, Epping, NSW 2121, Australia

M. Englund
Redfern Optical Components, Australian Technology Park, Eveleigh, NSW 1430, Australia

The integrated photonic lantern

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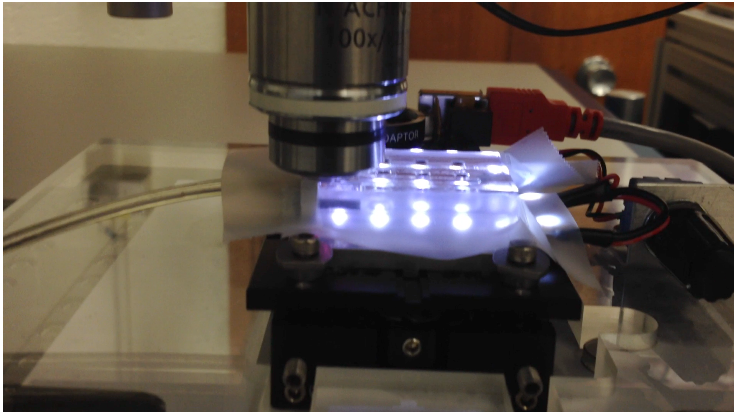
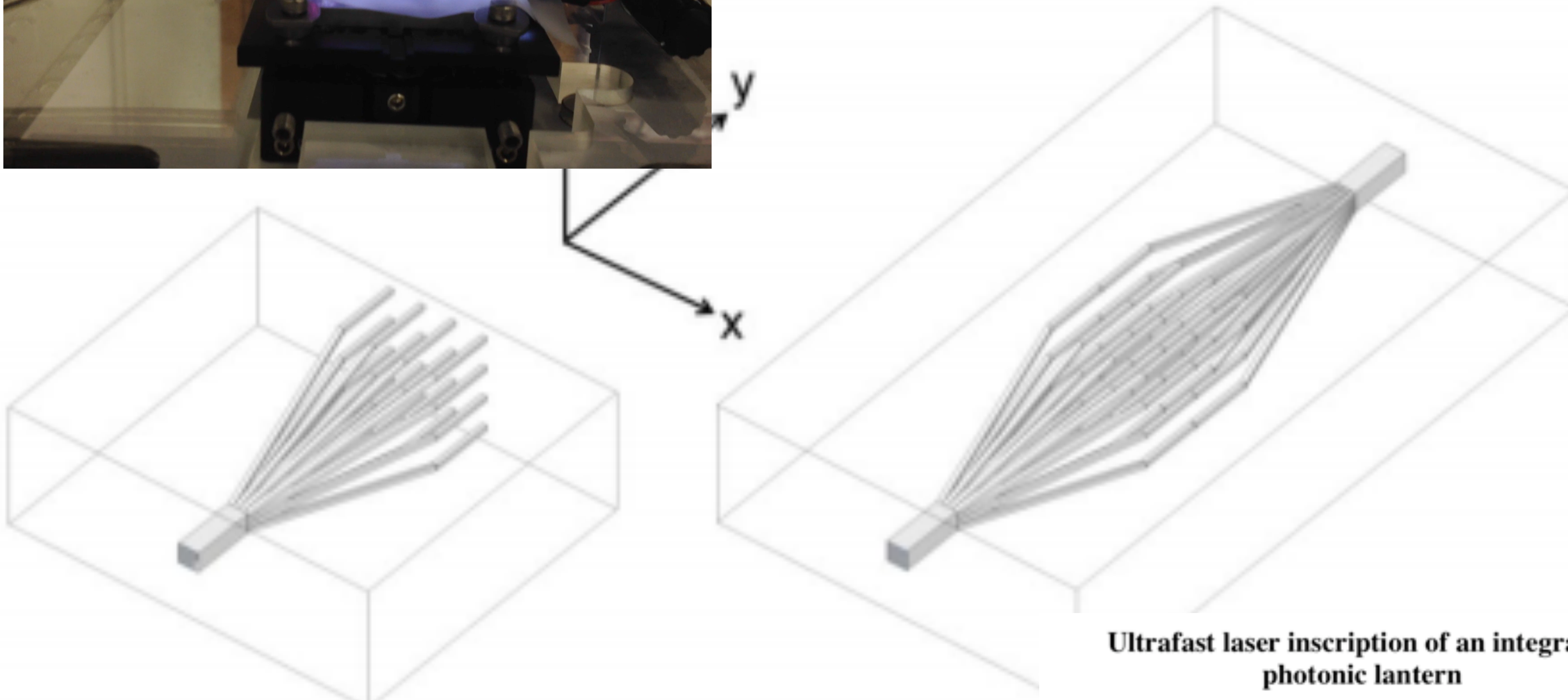




Ultrafast laser inscription of an integrated photonic lantern

R. R. Thomson,[1*] T. A. Birks,[2] S. G. Leon-Saval,[3] A. K. Kar,[1] and J. Bland-Hawthorn[3,4]

Thomson et al 2011

So why use photonics in Astronomy?

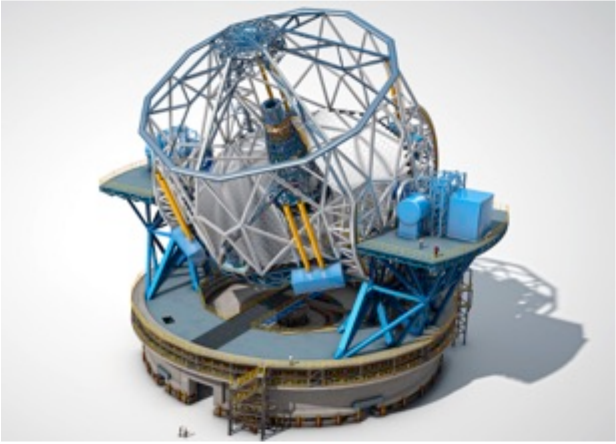
Instruments are getting bigger

For the ELT instruments will be around the size of a small apartment.

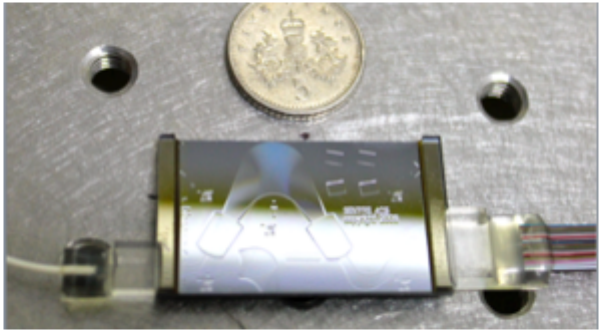
Can split the **parts** to make smaller more stable and add functionality.

This can be done using photonics e.g. cheap, small components.

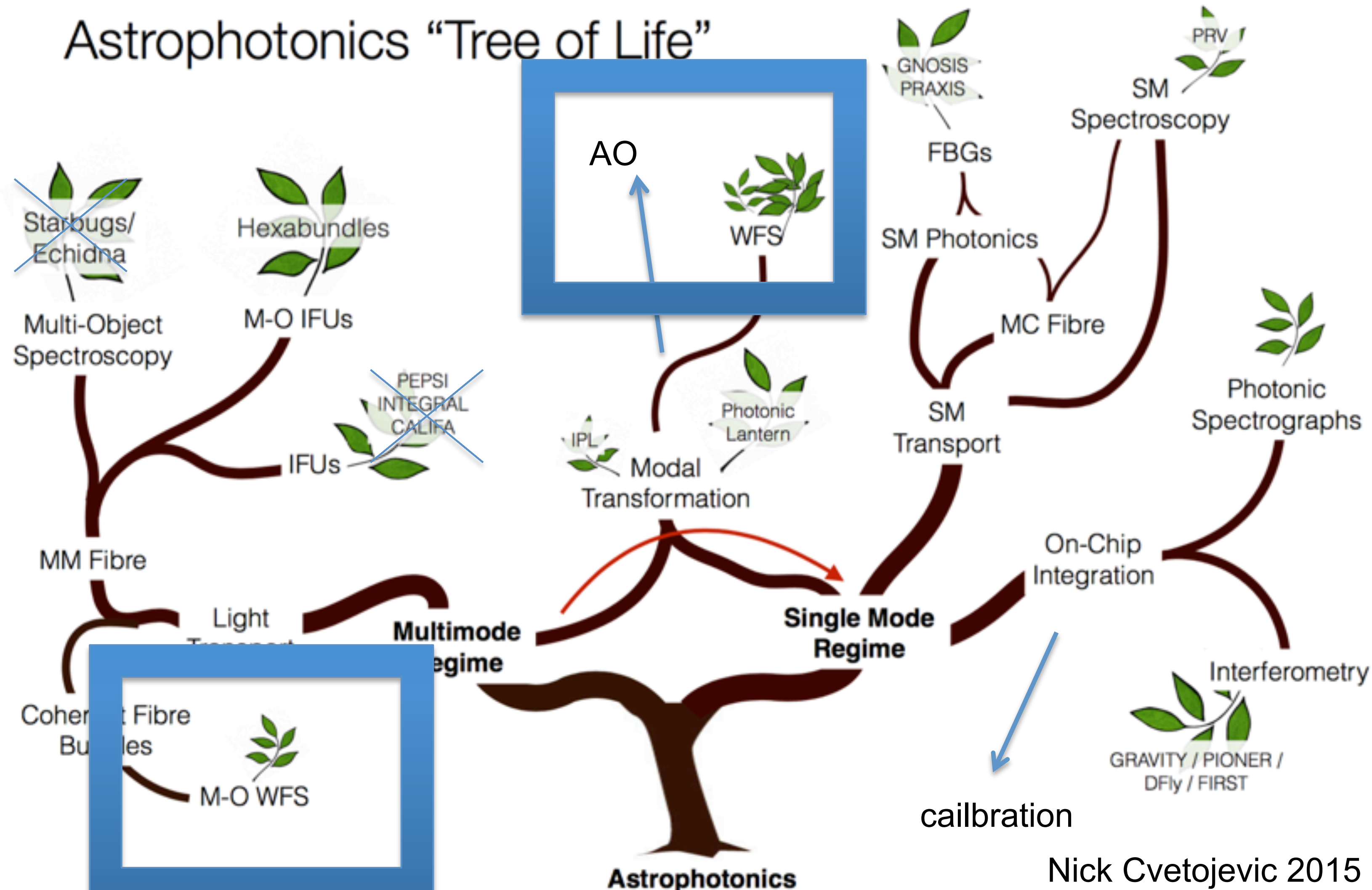
This is not the solution to all problems



Credit : ESO



Adaptive optics and wavefront sensing



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Coherent Fiber Bundles for Multi-object wavefront sensing

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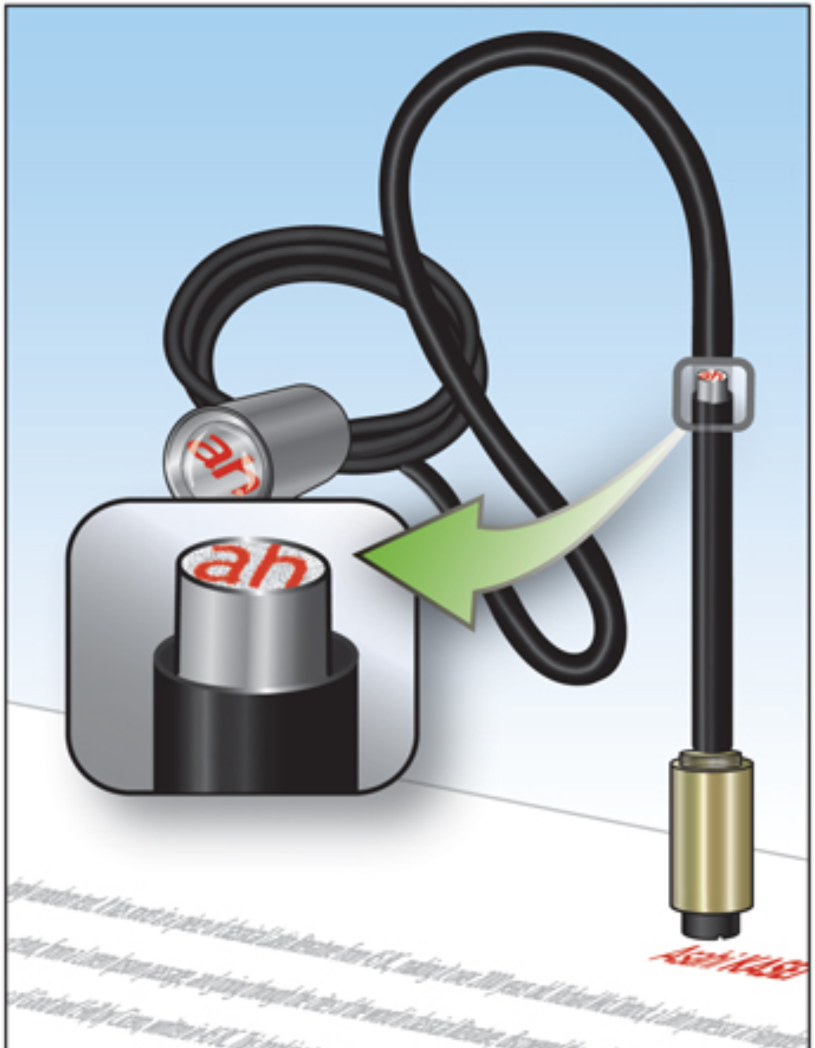

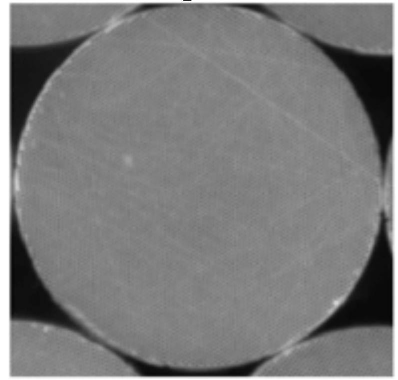

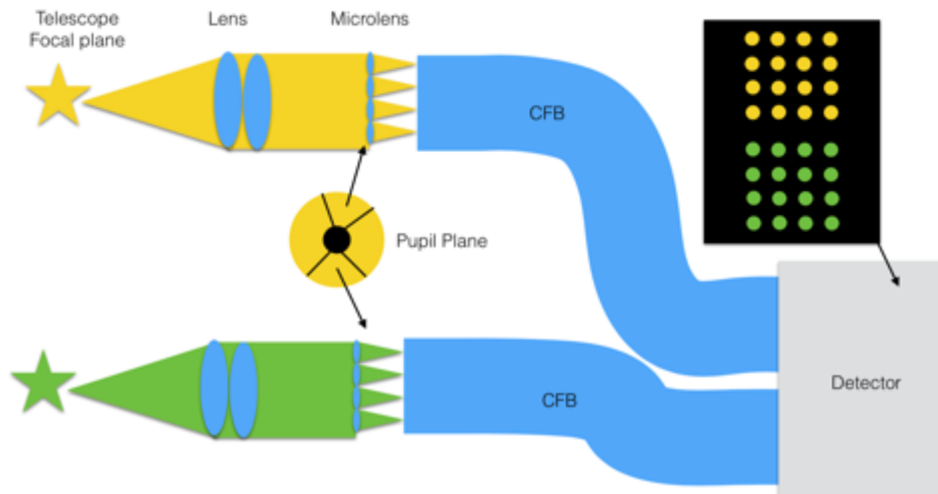

Miniaturized Shack-Hartmann Wavefront-Sensors for Starbugs

Michael Goodwin*[a], Samuel Richards[a,b], Jessica Zheng[a], Jon Lawrence[a], Sergio Leon-Saval[b], Alexander Argyros[b], Belen Alcalde[a]
[a]Australian Astronomical Observatory, PO Box 915, North Ryde, NSW 1670, Australia; [b]School of Physics, The University of Sydney NSW 2006, Australia

Low Order wavefront sensing using a photonic lantern

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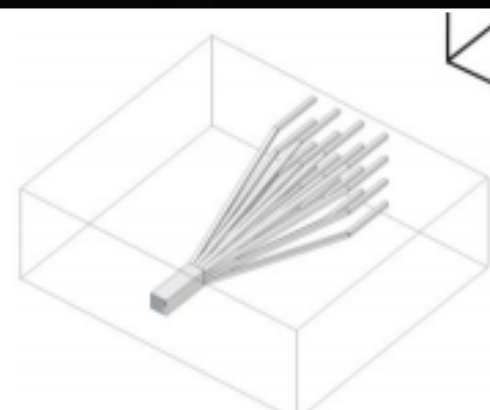
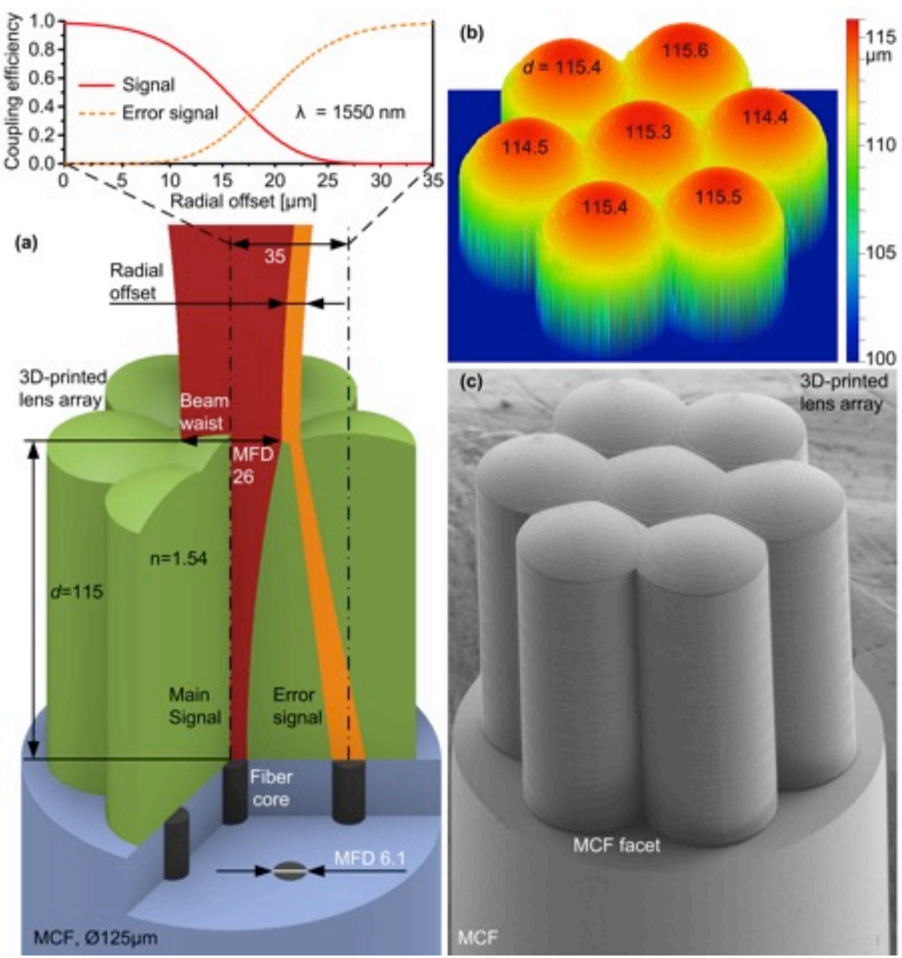


Wavefront sensing using a photonic lantern

Author(s): Mark Corrigan; Robert J. Harris; Robert R. Thomson; David G. MacLachlan; Jeremy Allington-Smith; Richard Myers; Tim Morris

Low order wavefront sensing using microlenses and a Multi-core fiber



Printed freeform lens arrays on multi-core fibers for highly efficient coupling in astrophotonic systems

Philipp-Immanuel Dietrich, Robert J. Harris, Matthias Blaicher, Mark K. Corrigan, Tim J. Morris, Wolfgang Freude, Andreas Quirrenbach, and Christian Koos

"AO on a chip"

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Self-aligning universal beam coupler

David A. B. Miller

Ginzton Laboratory, Stanford University, 348 Via Pueblo Mall, Stanford CA 94305-4088, USA
dabm@ee.stanford.edu

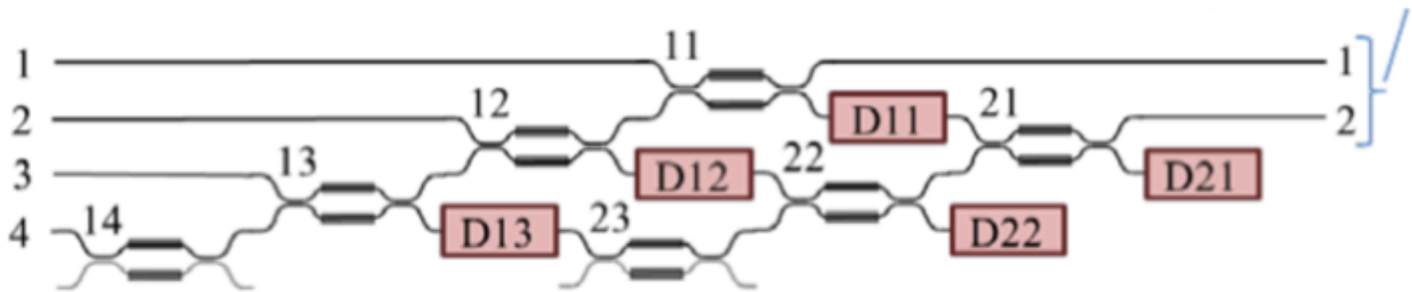

Fig. 3. Mach-Zehnder implementation with detectors. Device numberings correspond to those of Fig. 1. (a) Coupler for a single input beam. (b) Coupler as in (a) with dummy devices added to ensure equal path lengths and background losses. (c) Coupler for two simultaneous modes. The greyed-out lower portions in the bottom row of Mach-Zehnder devices are optional arms for symmetry only; simple controllable phase shifters could be substituted for these Mach-Zehnder devices.

Spectroscopy

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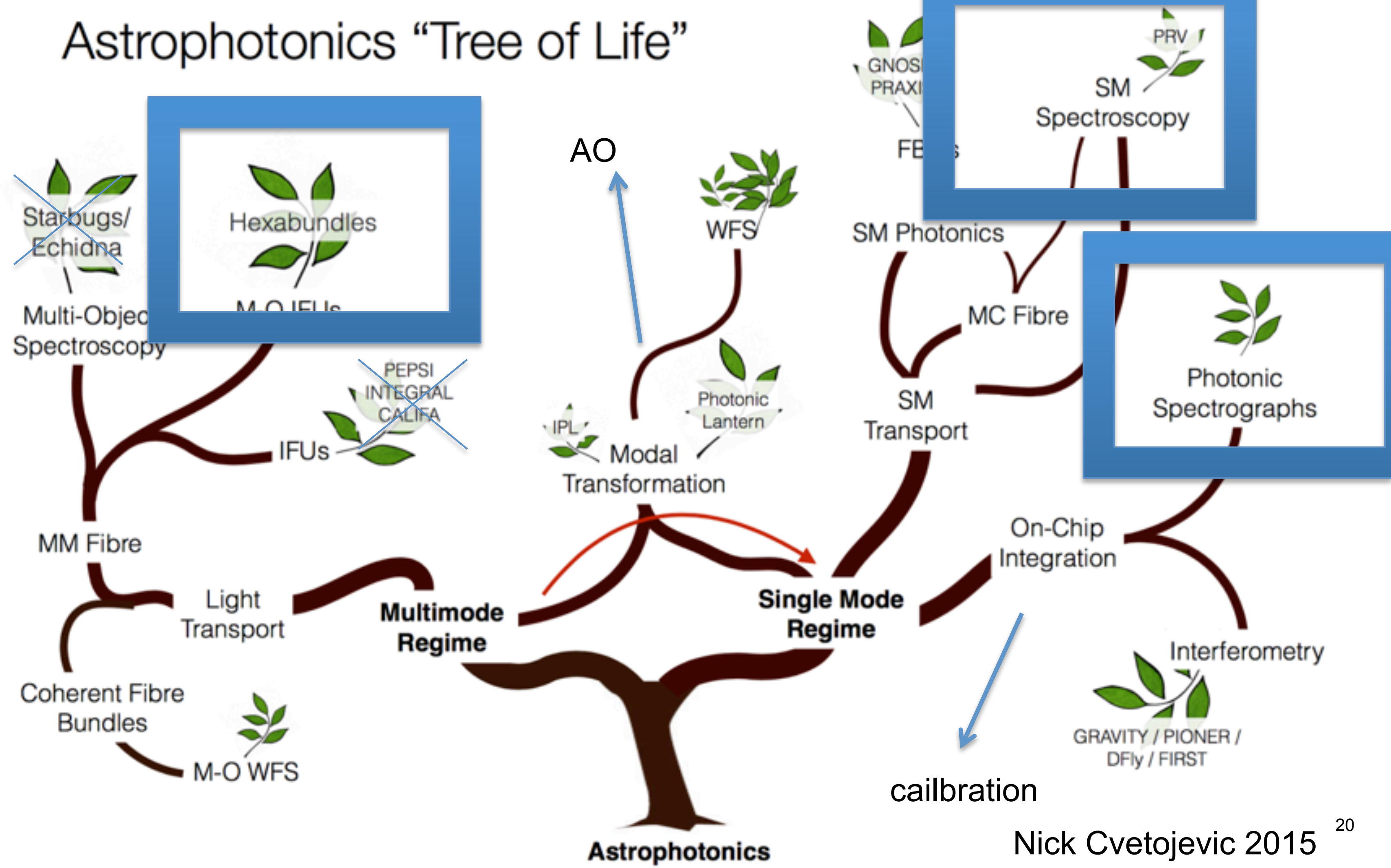

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Hexabundles

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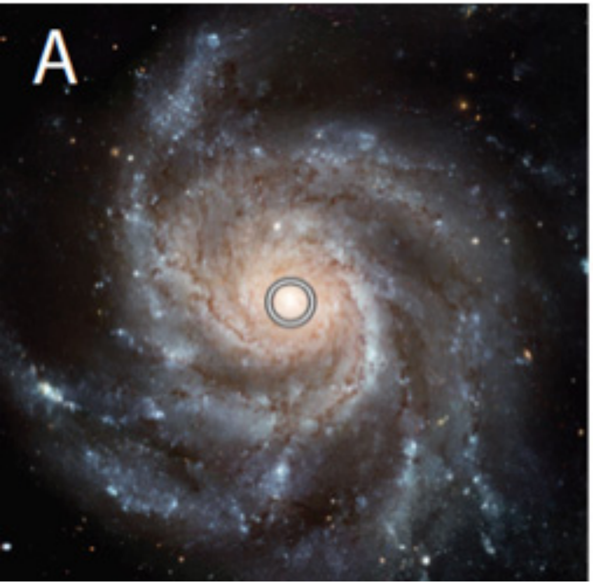

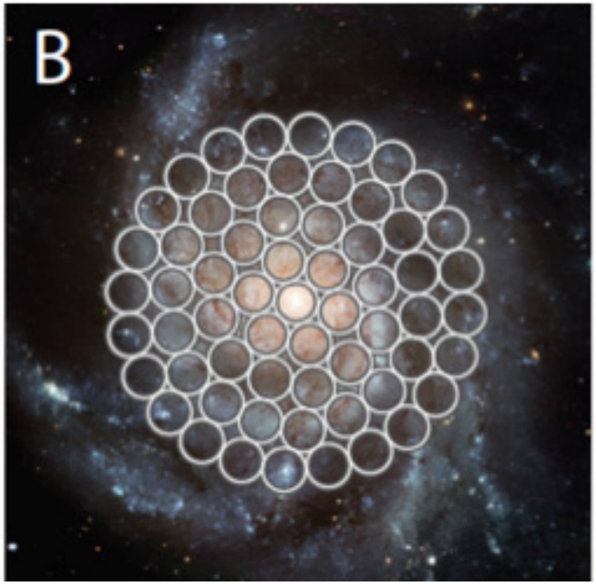

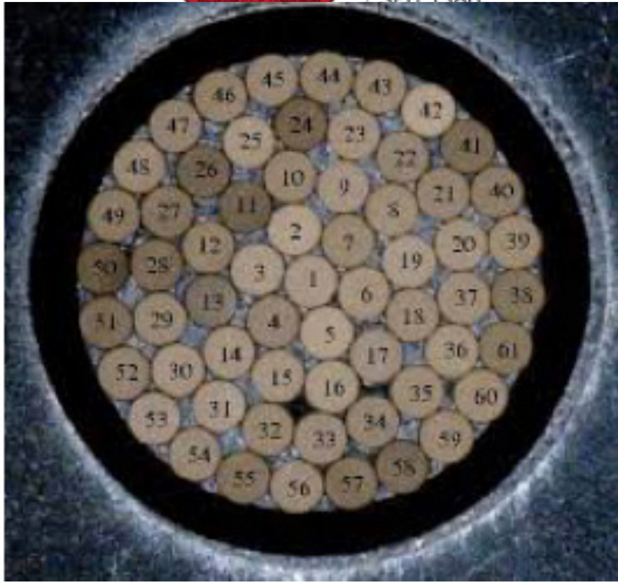

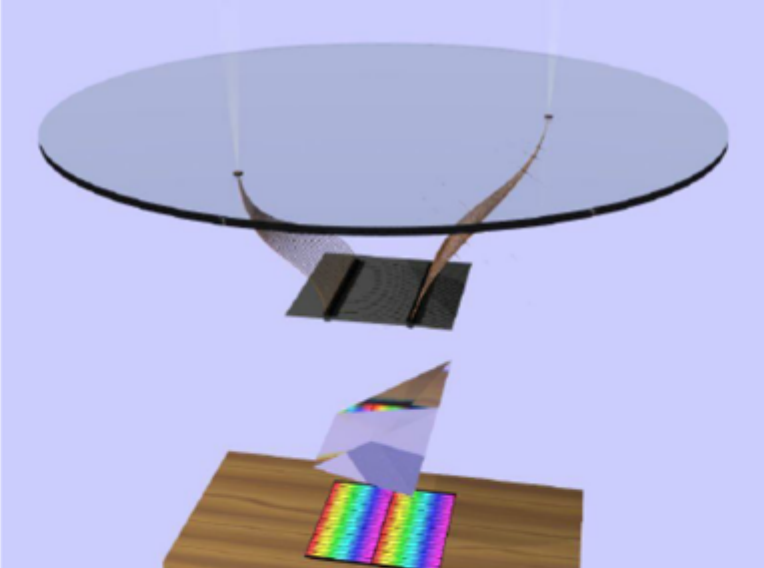

The Sydney-AAO Multi-object Integral field spectrograph

Authors

Croom, Scott M.; Lawrence, Jon S.; Bland-Hawthorn, Joss; Bryant, Julia J.; Fogarty, Lisa; Richards, Samuel; Goodwin, Michael; Farrell, Tony; Miziarski, Stan; Heald, Ron; Jones, D. Heath; Lee, Steve; Colless, Matthew; Brough, Sarah; Hopkins, Andrew M.; Bauer, Amanda E.; Birchall, Michael N.; Ellis, Simon; Horton, Anthony; Leon-Saval, Sergio; Lewis, Geraint; López-Sánchez, Á. R.; Min, Seong-Sik; Trinh, Christopher; Trowland, Holly

The Hector Survey: integral field spectroscopy of 100,000 galaxies

J. Bland-Hawthorn[1]

Single Mode spectrographs – Photonic Tiger

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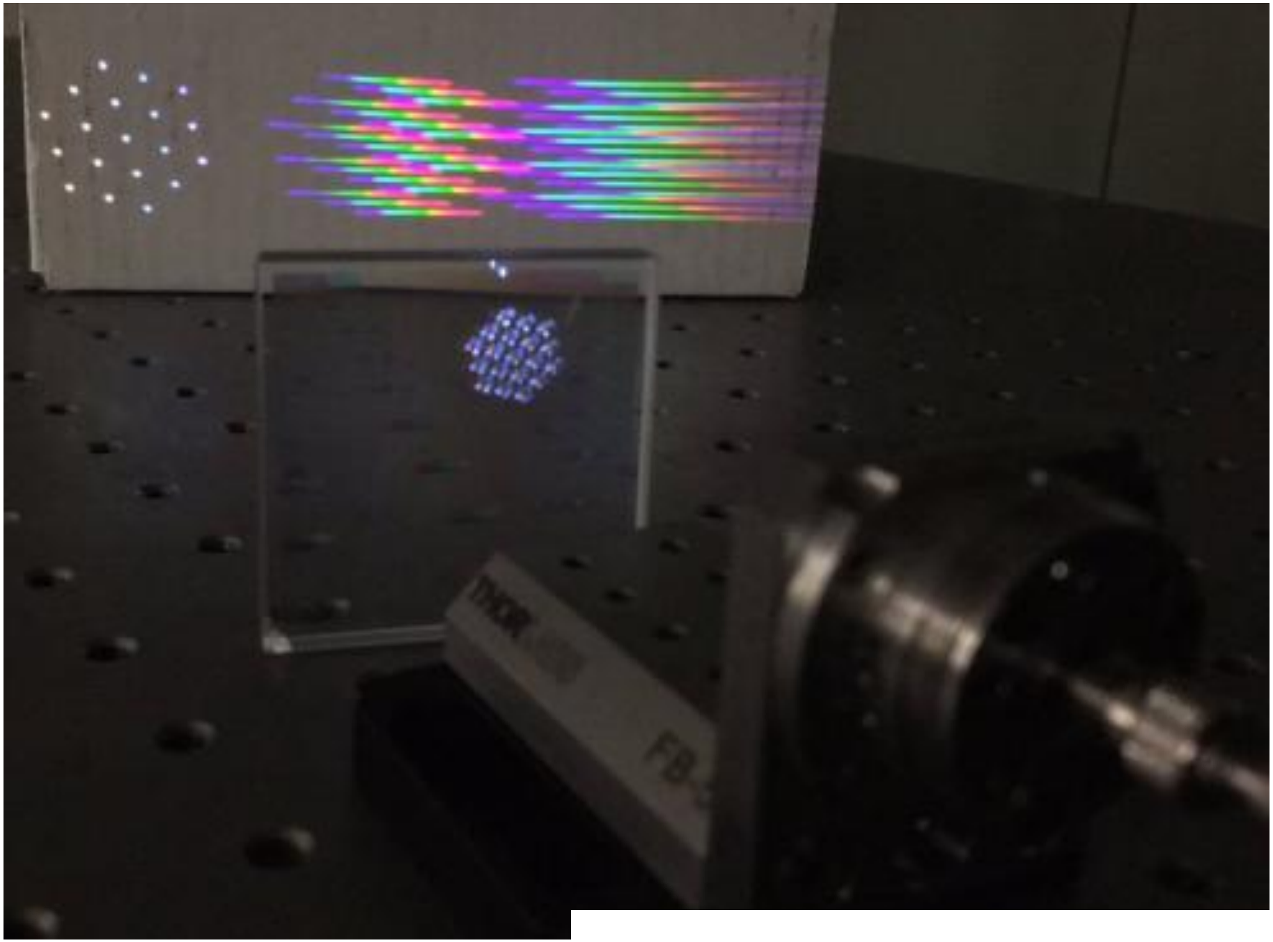
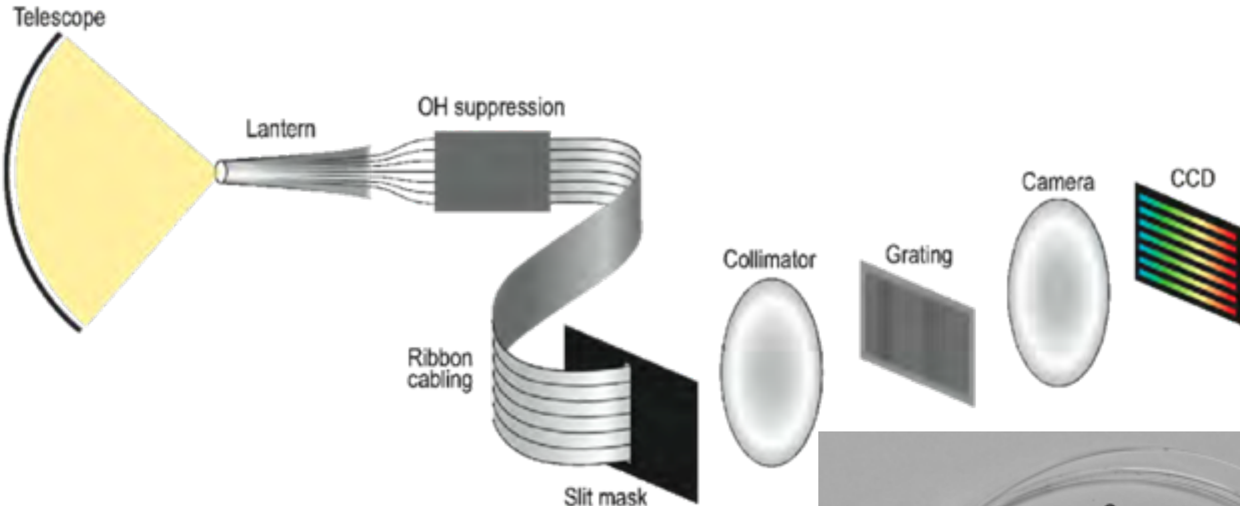
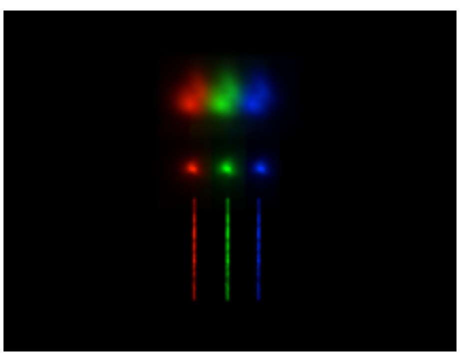


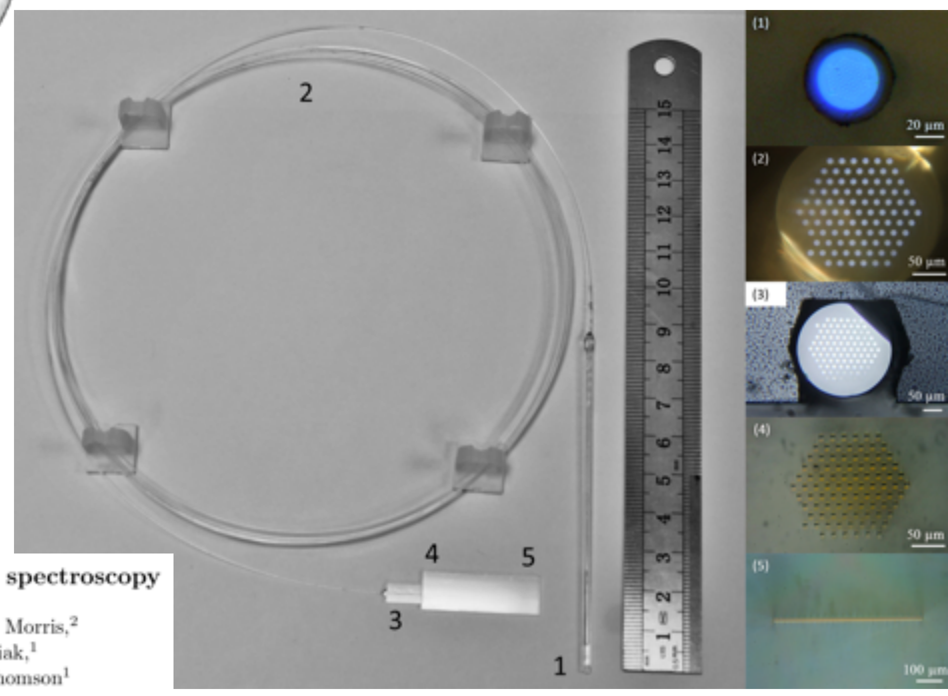
The Photonic TIGER: a multicore fiber-fed spectrograph

Sergio G. Leon-Saval, Christopher H. Betters and Joss Bland-Hawthorn
School of Physics, University of Sydney, NSW 2006, Australia

Reformatting Single Mode spectrographs







Efficient photonic reformatting of celestial light for diffraction-limited spectroscopy

David G. MacLachlan,[1,*] Robert J. Harris,[2,†] Itandehui Gris-Sánchez,[3] Timothy J. Morris,[2]
Debaditya Choudhury,[1] Eric Gendron,[4] Alastair G. Basden,[2] Izabela J. Spaleniak,[1]
Alexander Arriola,[1] Tim A. Birks,[3] Jeremy R. Allington-Smith,[2] and Robert R. Thomson[1]

Arrayed Waveguide Gratings for spectroscopy

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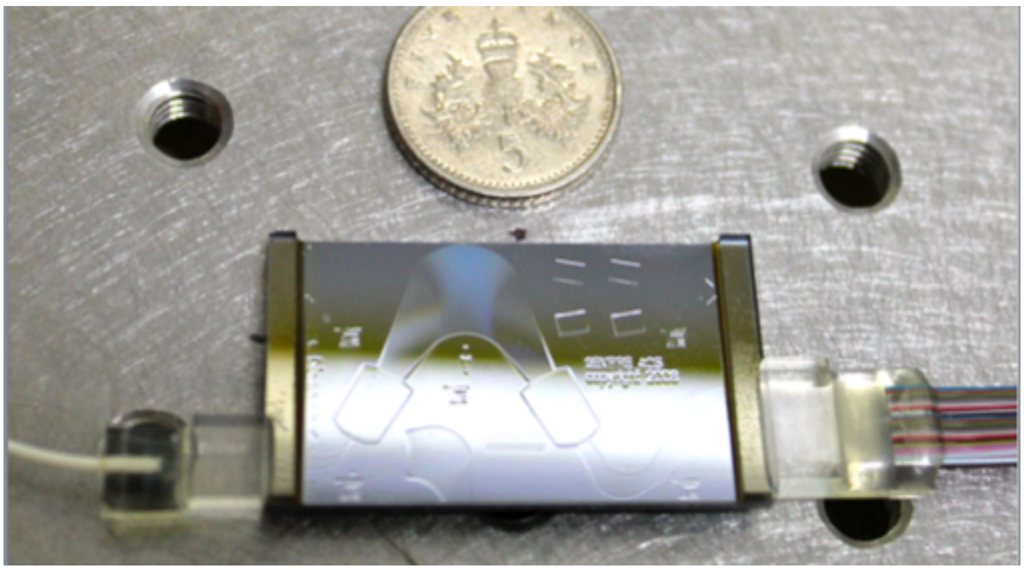
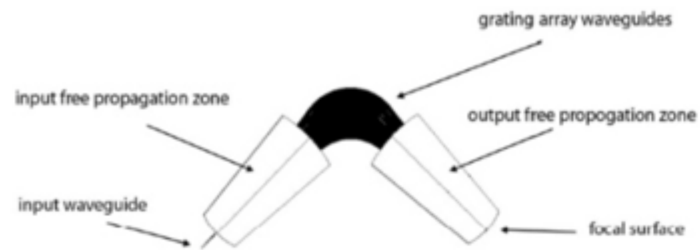
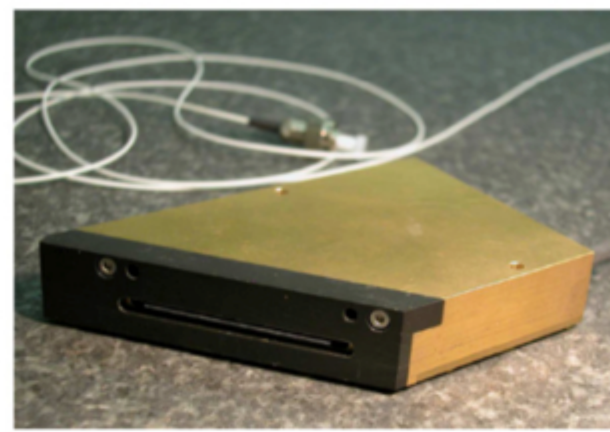


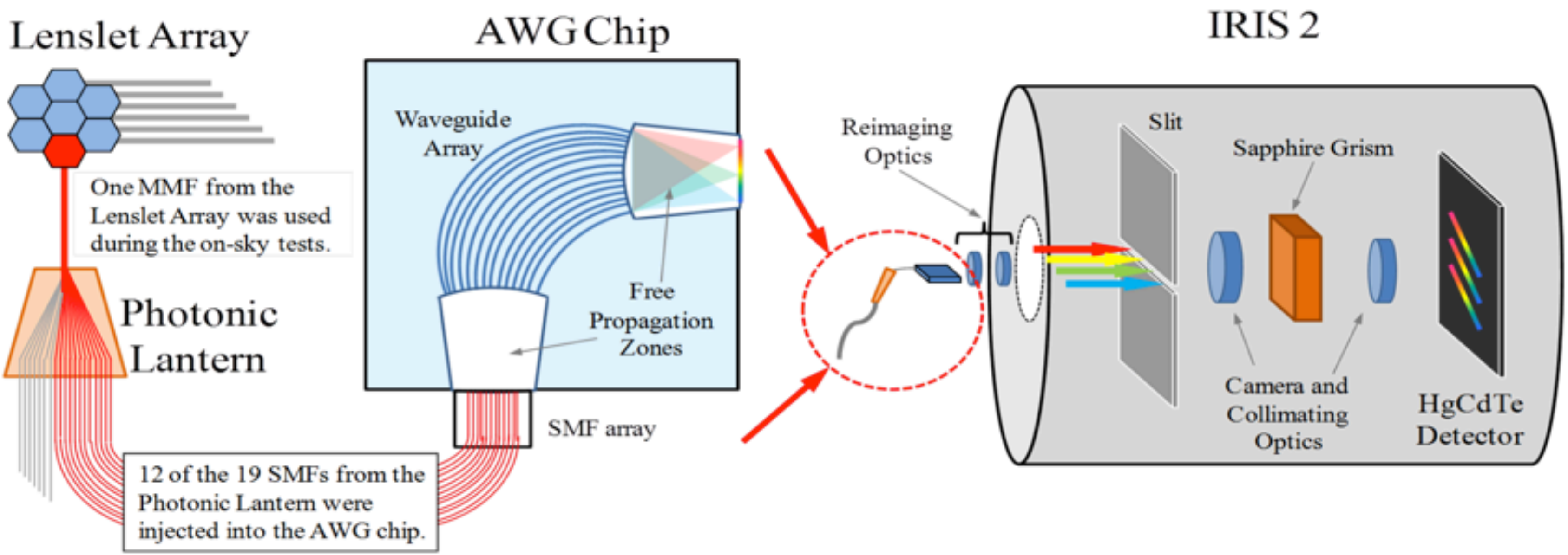




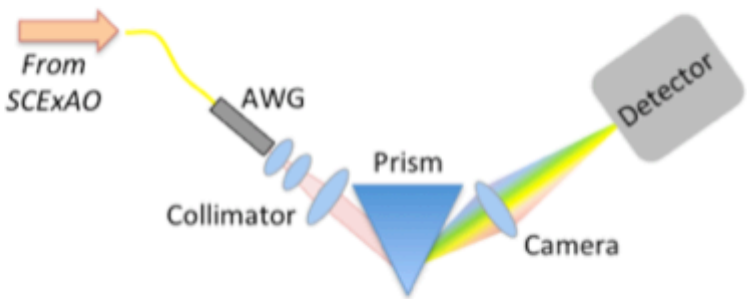
Characterization and on-sky demonstration of an integrated photonic spectrograph for astronomy

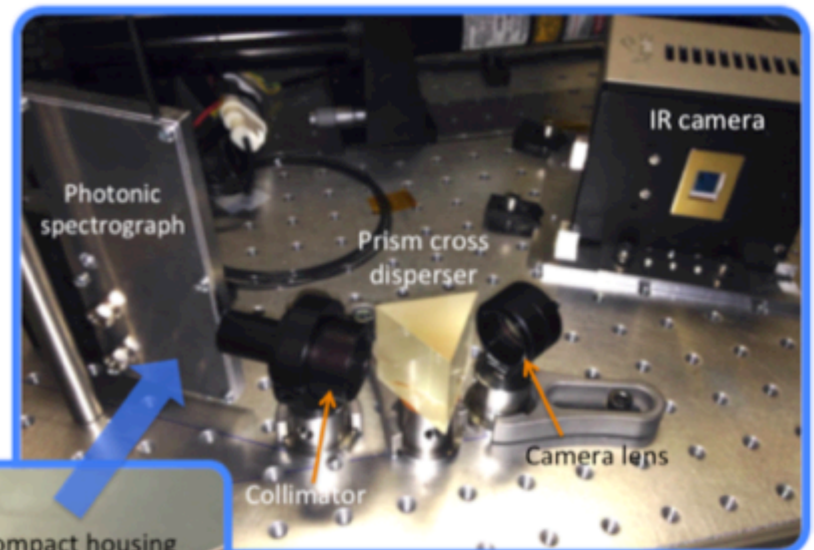
N. Cvetojevic,[1] J. S. Lawrence,[1,2,*] S. C. Ellis,[3] J. Bland-Hawthorn,[3] R. Haynes,[1] and A. Horton[1]

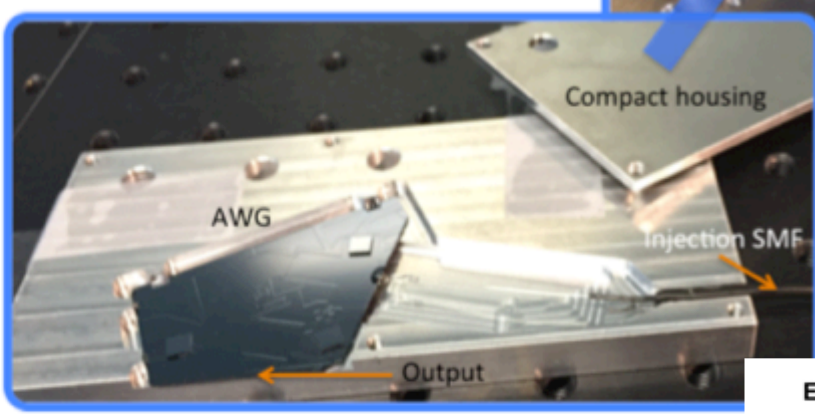
Arrayed Waveguide Grating spectrograph – a full system



Single Mode Spectrographs with XAO







Efficient injection from large telescopes into single-mode fibres: Enabling the era of ultra-precision astronomy

N. Jovanovic[1,2*], C. Schwab[2,3], O. Guyon[1,4,5,6], J. Lozi[1], N. Cvetojevic[3,7,8], F. Martinache[9], S. Leon-Saval[7], B. Norris[7], S. Gross[2,8], D. Doughty[1], T. Currie[1] and N. Takato[1]

RHEA – a single mode Integral Field Unit

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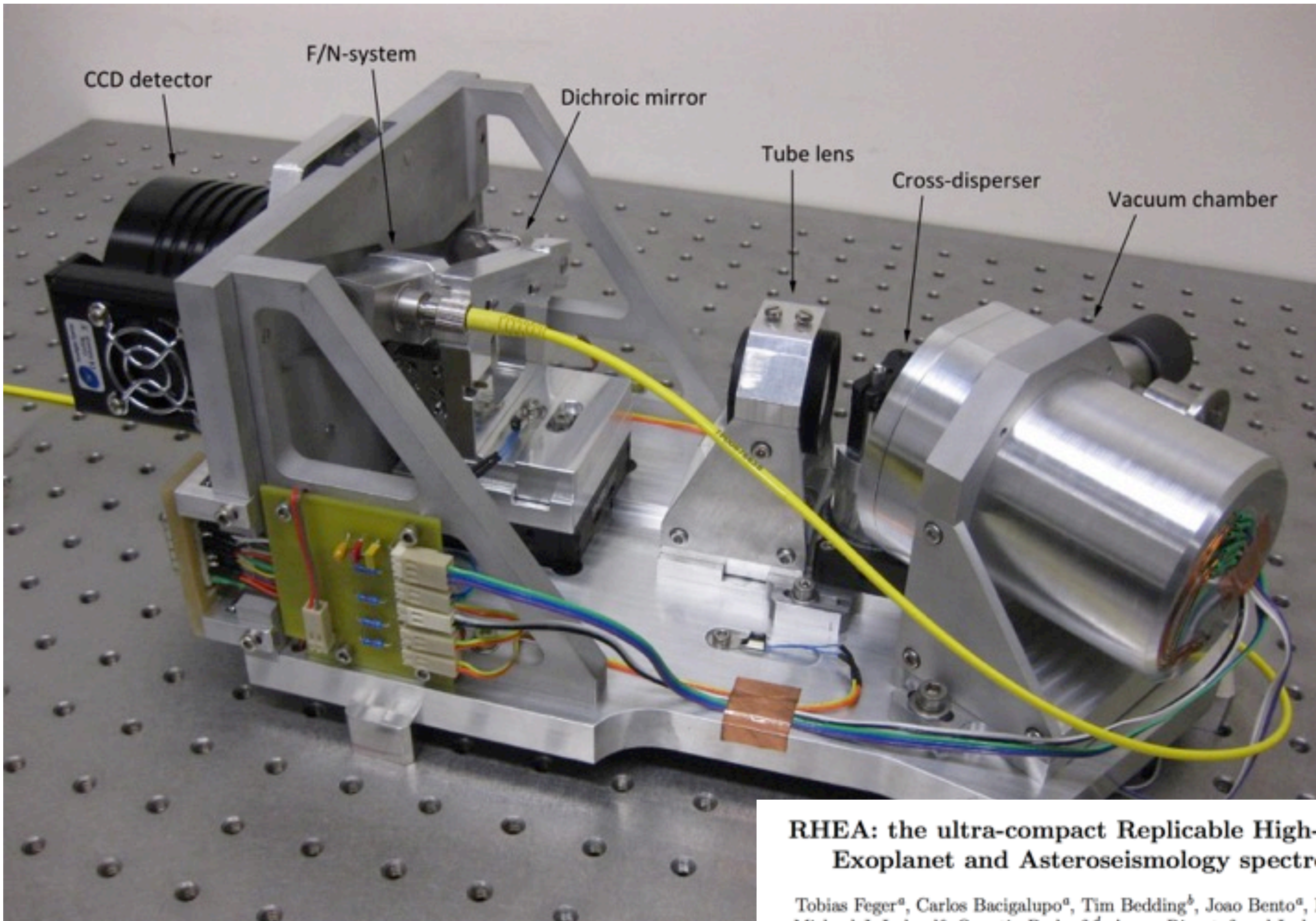

RHEA: the ultra-compact Replicable High-resolution Exoplanet and Asteroseismology spectrograph

Tobias Feger[a], Carlos Bacigalupo[a], Tim Bedding[b], Joao Bento[a], David Coutts[a], Michael J. Ireland[c], Quentin Parker[a,d], Aaron Rizzuto[a] and Izabella Spaleniak[a]

Interferometry

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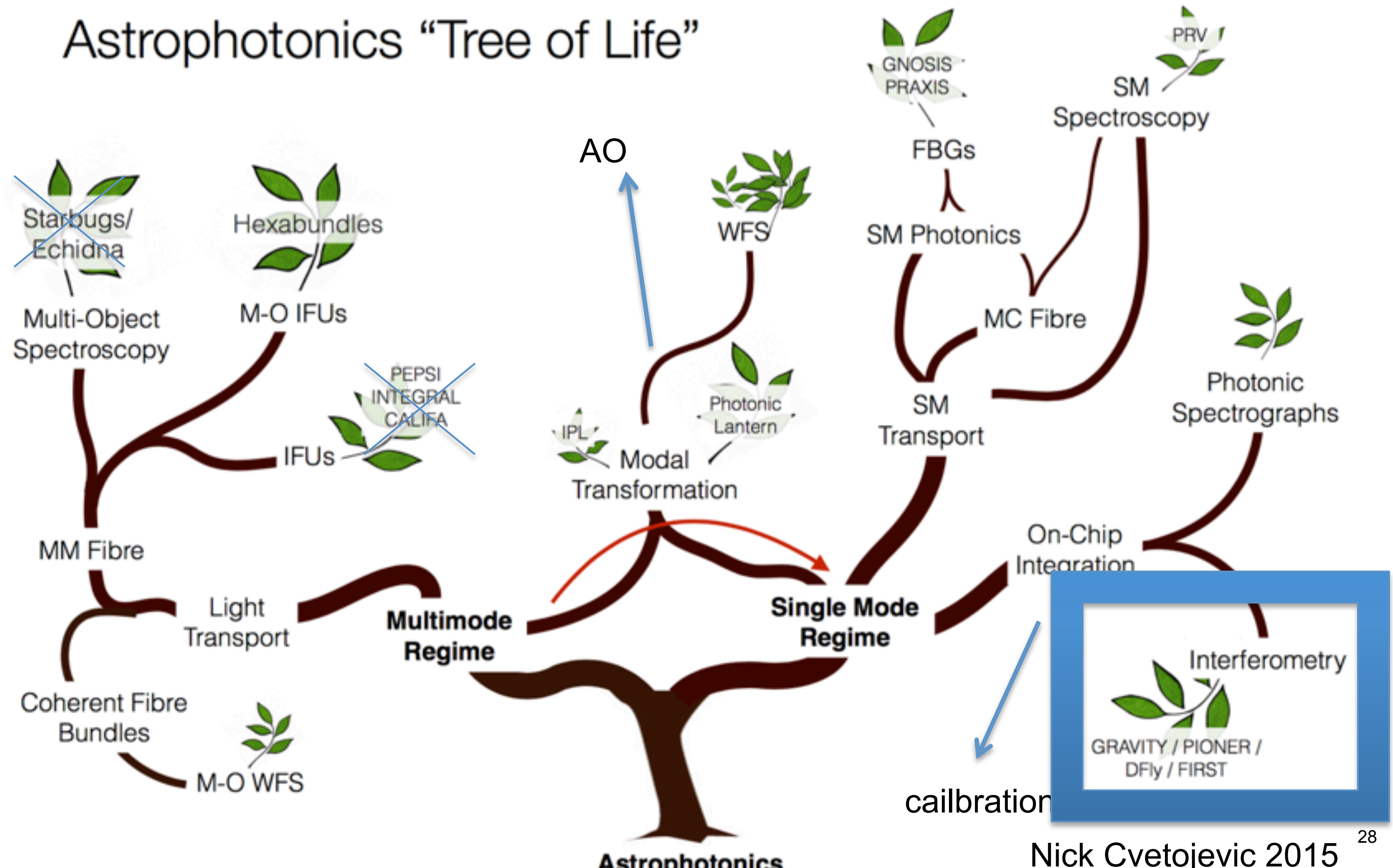
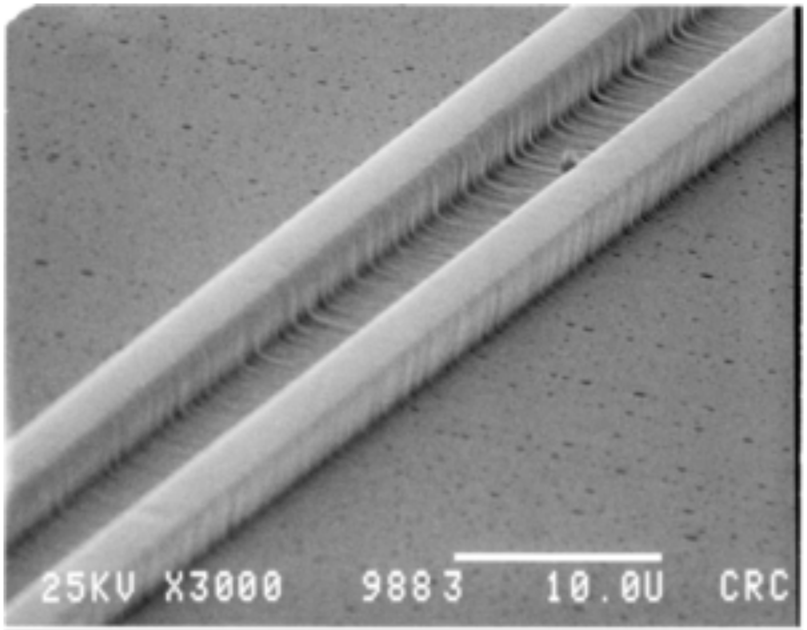
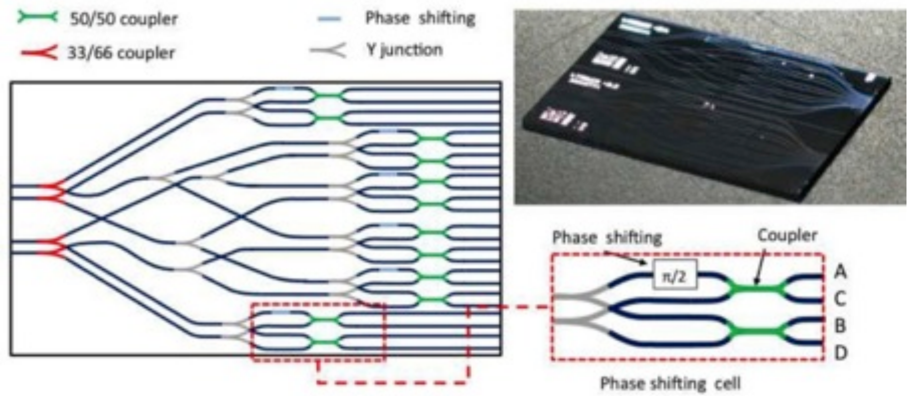


Nick Cvetojevic 2015

Beam combiners - Lithography



Viens, et. al. *Proc. SPIE* (1999)



MPE website

Ultrafast Laser Inscribed beam combiners for pupil remapping

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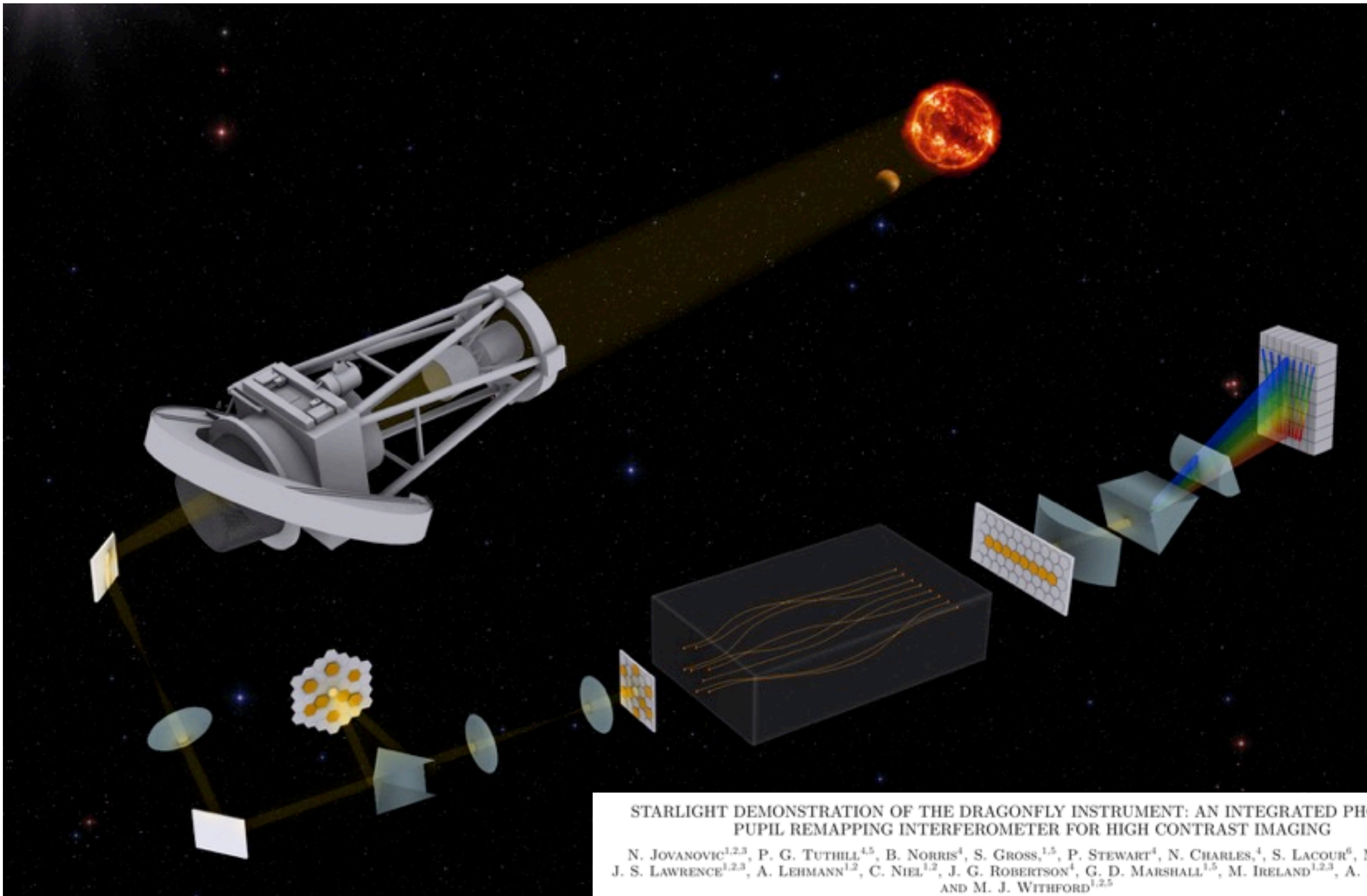
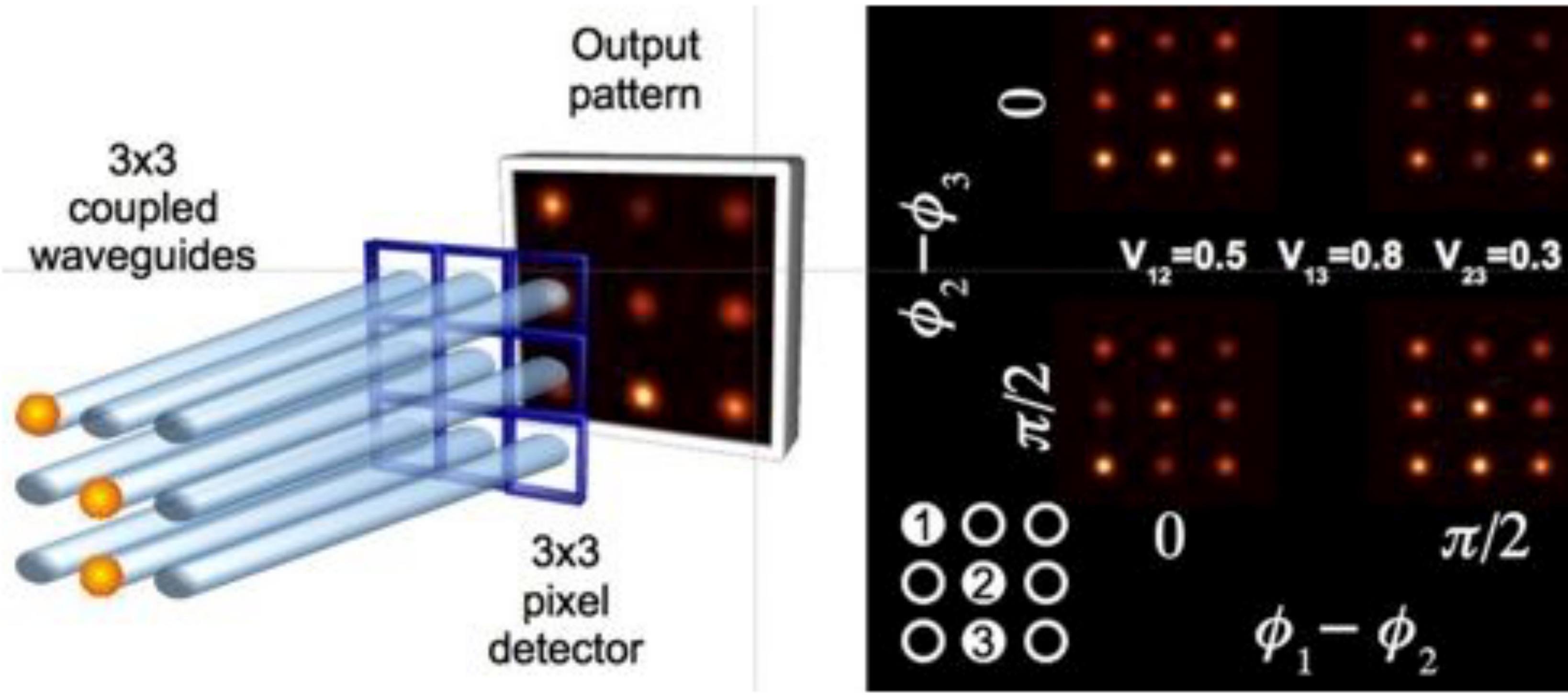


STARLIGHT DEMONSTRATION OF THE DRAGONFLY INSTRUMENT: AN INTEGRATED PHOTONIC PUPIL REMAPPING INTERFEROMETER FOR HIGH CONTRAST IMAGING

N. Jovanovic[1,2,3], P. G. Tuthill[4,5], B. Norris[4], S. Gross,[1,5], P. Stewart[4], N. Charles,[4], S. Lacour[6], M. Ams[1,5], J. S. Lawrence[1,2,3], A. Lehmann[1,2], C. Niel[1,2], J. G. Robertson[4], G. D. Marshall[1,5], M. Ireland[1,2,3], A. Fuerbach[1,5] and M. J. Withford[1,2,5]

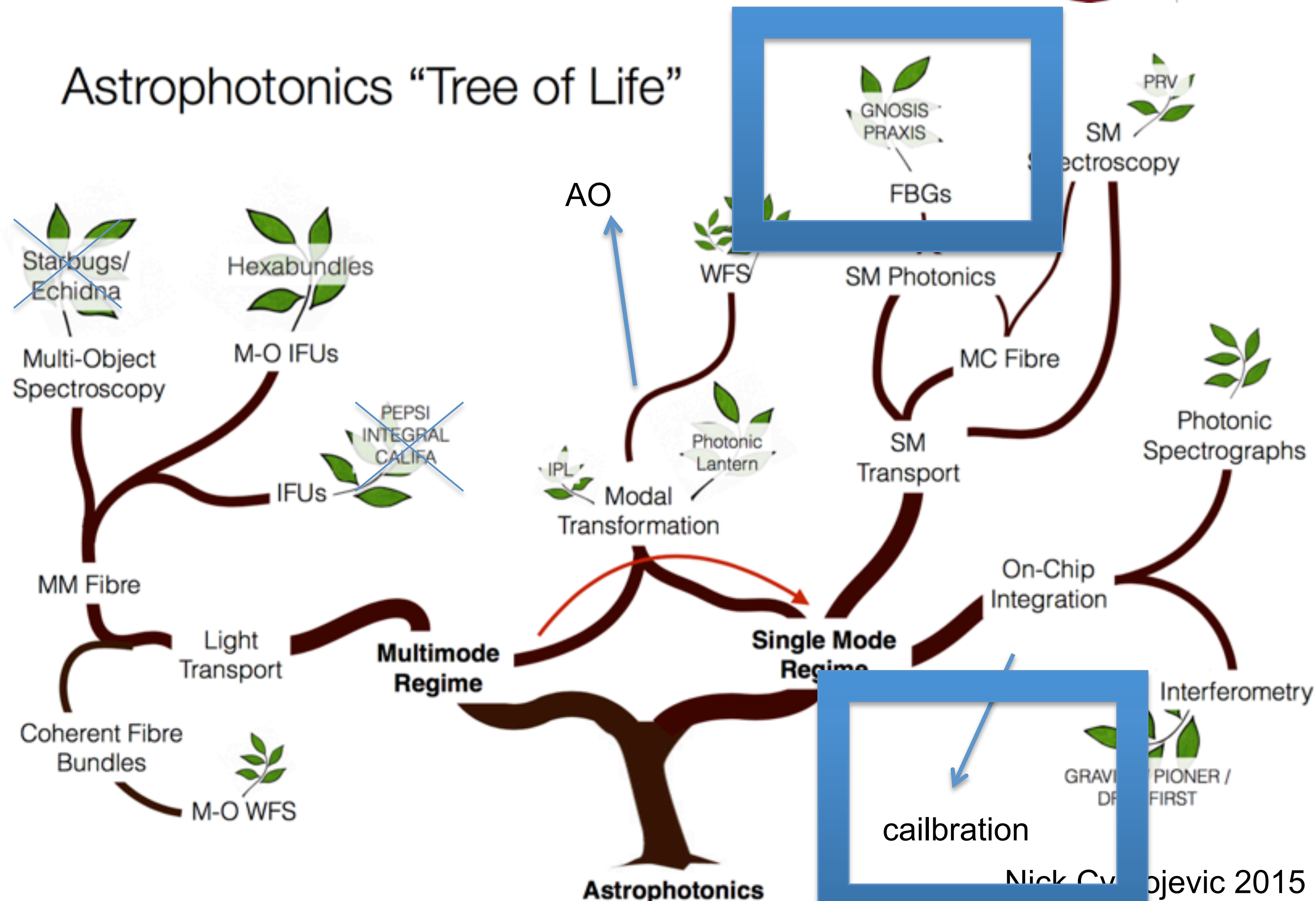
Ultrafast Laser Inscribed beam combiners for interferometry



Interferometric combination of beams from three different astronomical telescopes in an array of evanescently coupled laser written waveguides for the retrieval of the relative phases between the signals of the telescopes.

Taken from Stefano Minardi's website

Calibration and suppression



Fiber Bragg gratings, suppress the night sky

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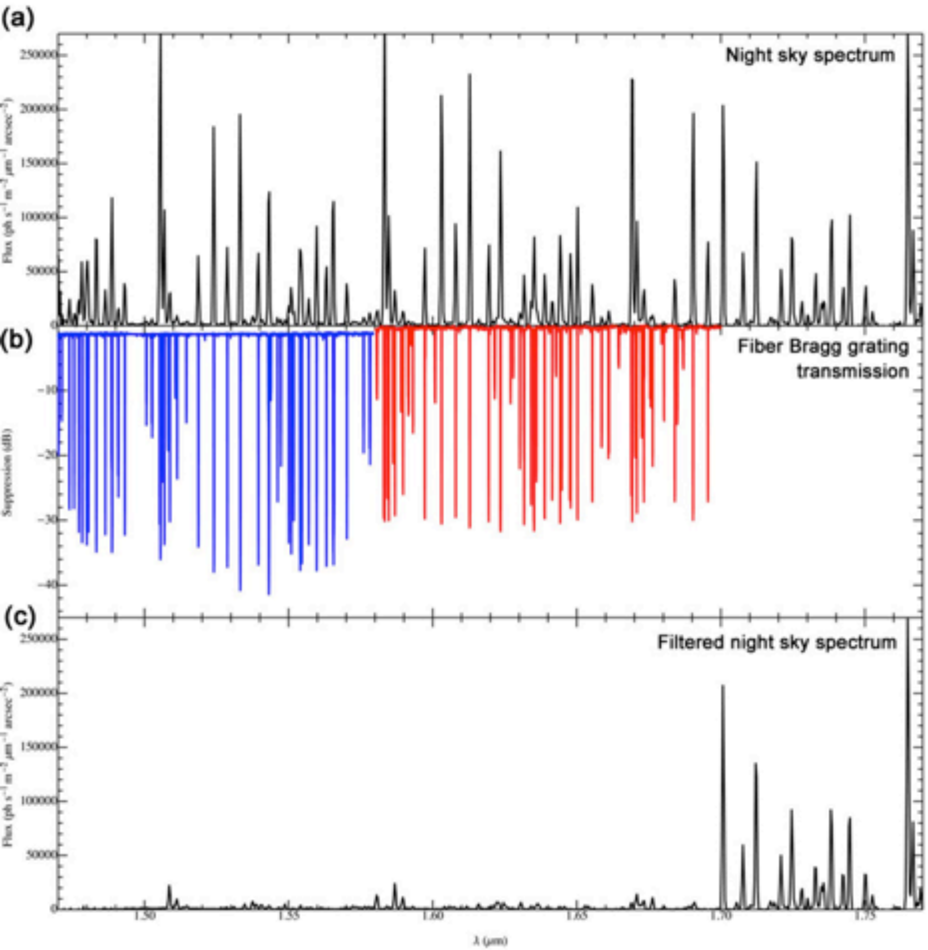
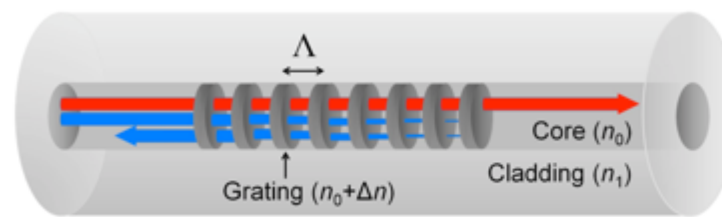
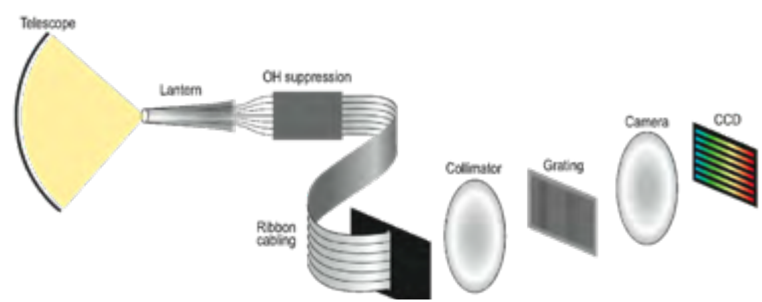


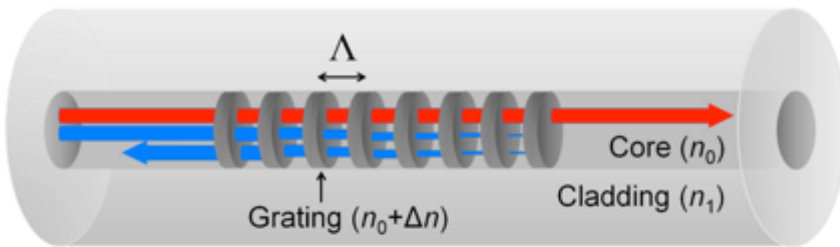


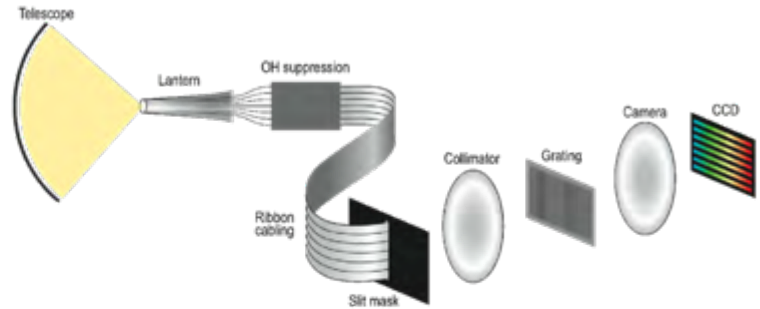


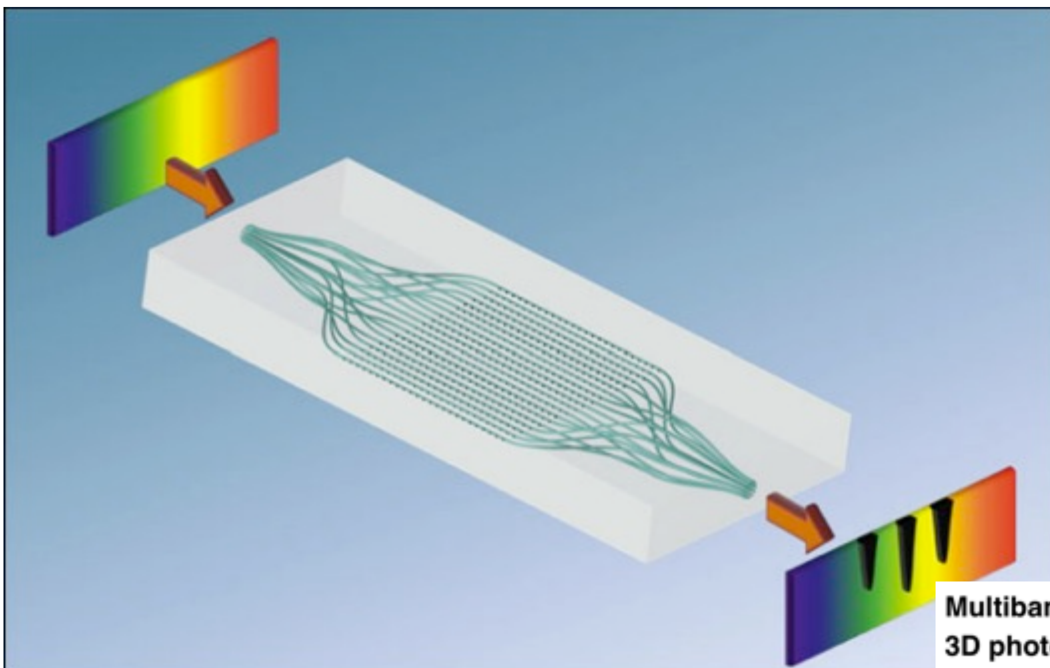
A complex multi-notch astronomical filter to suppress the bright infrared sky

J. Bland-Hawthorn,[1,2] S.C. Ellis,[1,3] S.G. Leon-Saval,[1,2] R. Haynes,[3,4] M.M. Roth,[4] H.-G. Löhmannsröben,[5] A.J. Horton,[3] J.-G. Cuby,[6] T.A. Birks,[7] J.S. Lawrence,[3,8] P. Gillingham,[3] S.D. Ryder,[3] C. Trinh.[1]

Fiber Bragg gratings – created with Ultrafast Laser Inscription







Multiband processing of multimode light: combining 3D photonic lanterns with waveguide Bragg gratings

Izabela Spaleniak,[1,2,*] Simon Gross,[1,3] Nemanja Jovanovic,[4] Robert J. Williams,[1] Jon S. Lawrence,[1,2,5] Michael J. Ireland,[1,2,5] and Michael J. Withford[1,2,3]

Ring resonators for night sky suppression

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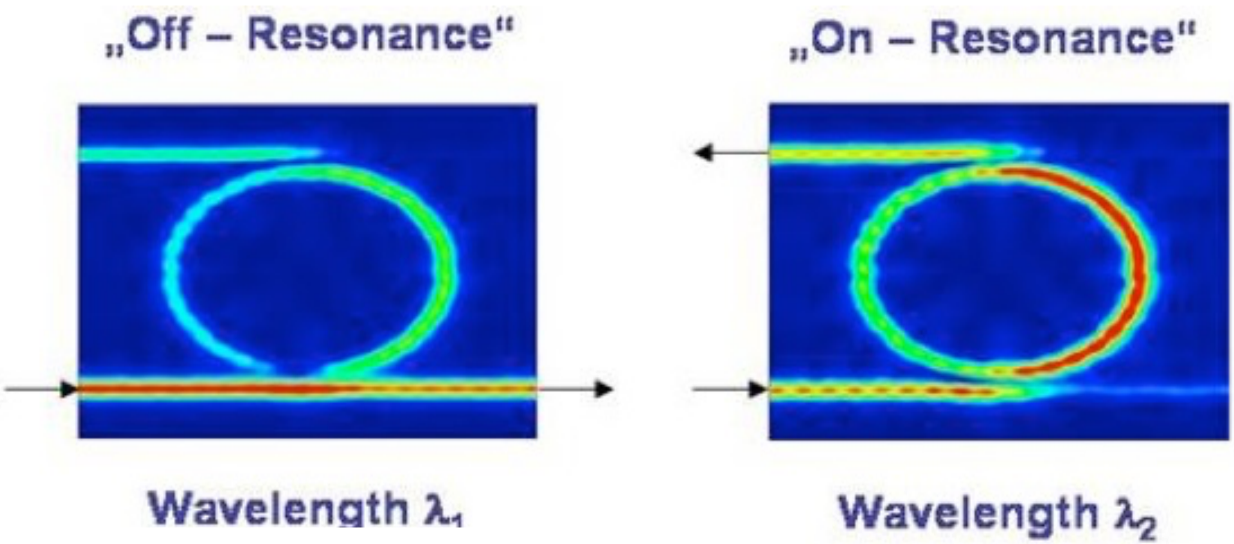
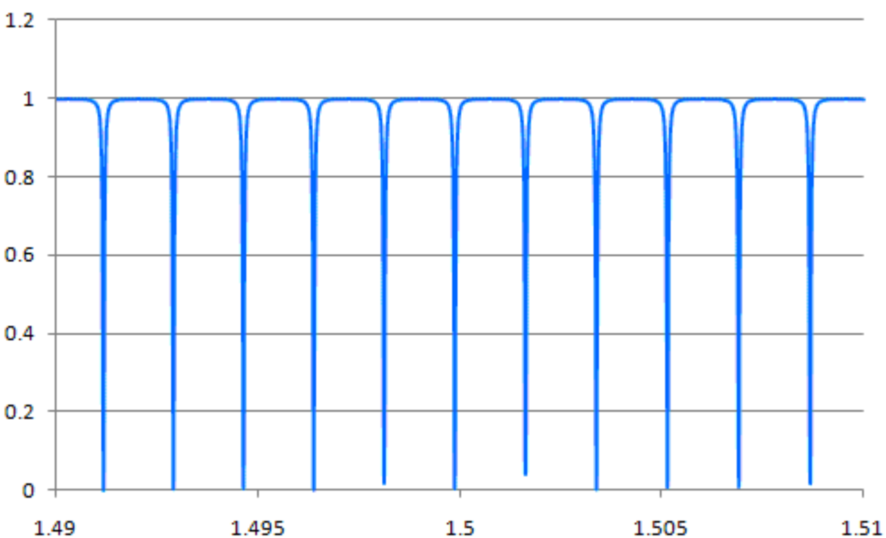
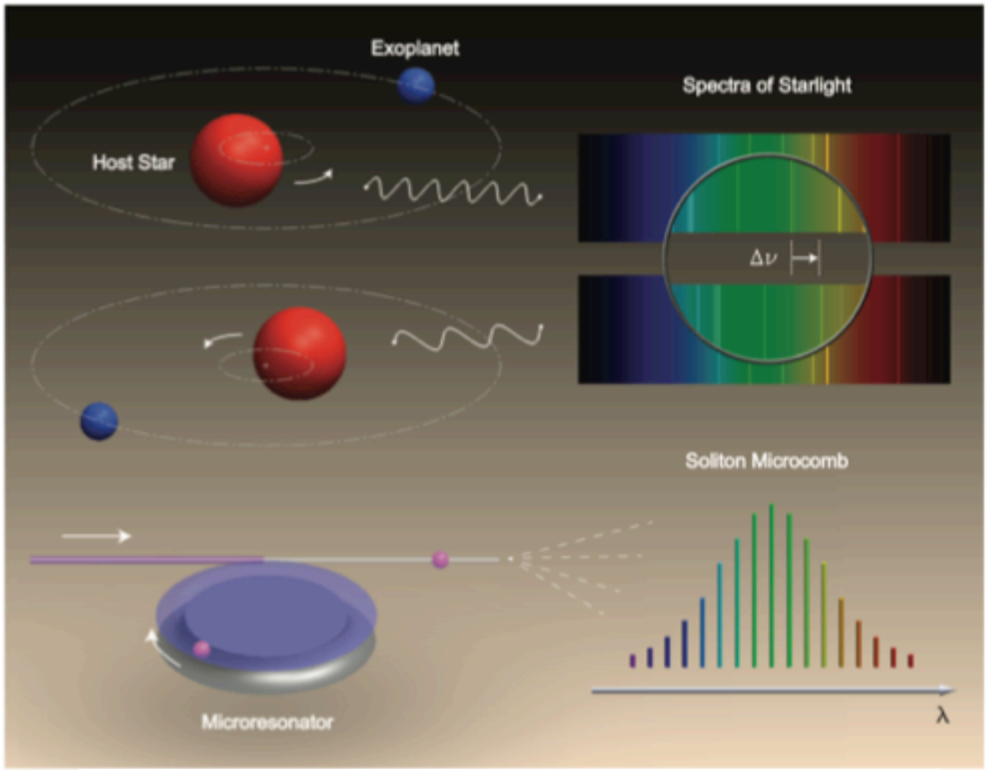




Photonic ring resonator filters for astronomical OH suppression

S. C. ELLIS,[1,2,*] S. KUHLMANN,[3] K. KUEHN,[1] H. SPINKA,[3] D. UNDERWOOD,[3] R. R. GUPTA,[3] L. OCOLA[3], P. LIU,[4] G. WEI,[4] N. P. STERN,[4] J. BLAND-HAWTHORN,[2] AND P. TUTHILL[2]

Astrocombs for wavelength calibration



Searching for Exoplanets Using a Microresonator Astrocomb

Myoung-Gyun Suh[1], Xu Yi[1], Yu-Hung Lai[1], S. Leifer[2], Ivan S. Grudinin[2], G. Vasisht[2], Emily C. Martin[4], Michael P. Fitzgerald[4], G. Doppmann[5], J. Wang[6], D. Mawet [6,2], Scott B. Papp[3], Scott A. Diddams[3], C. Beichman[7,*], Kerry Vahala[1,*]
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Conclusions

Astrophotonics can improve telescope performance, in the right areas

Lots of technology development going on

We will hopefully see the results in the near future

Plenty of new technologies to explore