# A multi-core integral field unit

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# Why am I excited?

I am finally leading my own project again (well, at least the Heidelberg side)

Testing new technology to characterise exoplanets

It can fit to diffraction limited systems (XAO, with caveats)

We’re doing it on a shoestring budget (always makes things more exciting?)

Great team (Leiden, INAF Brera, HW, Bath, Durham, KIT, MPIA)

Combines all the things I do (and more), finally a full instrument

Plenty of future potential

# How did this happen?

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I met Sebastian Haffert (and Santiago) in 2014

Wanted to do a project together since around 2016, solidified last year

Needs fibre/reformatter - Durham, Bath, Heriot-Watt (WP6 leadership)

Needs microlenses – KIT

Needs VPH grating - WP7 people through writing a mid term summary

# Why do it?

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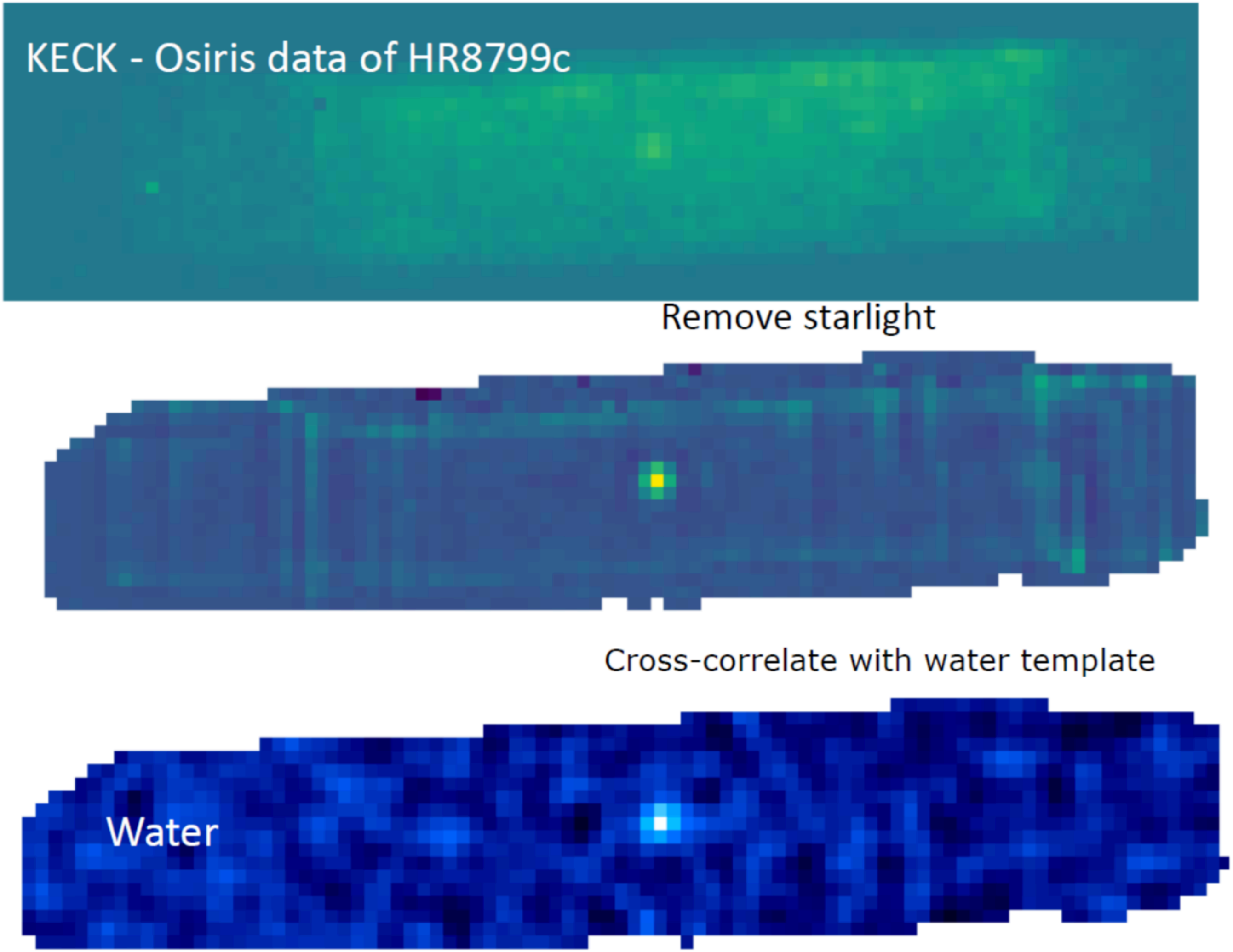

# What exists that can do similar things

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A non extensive list (low, medium, high res)

SCExAO, Charis R <100, JHK, lenslet

SPHERE, IFU R ~100, lenslet

GPI R ~100, lenslet

KECK OSIRIS, R~ few K (lenslet)

Sinfoni, JHK, R~ few K (slicer)

MUSE, Vis, R~ few K, (slicer)

CRIRES (R = 100,000)

Several prototype fibres (RHEA, IRD)

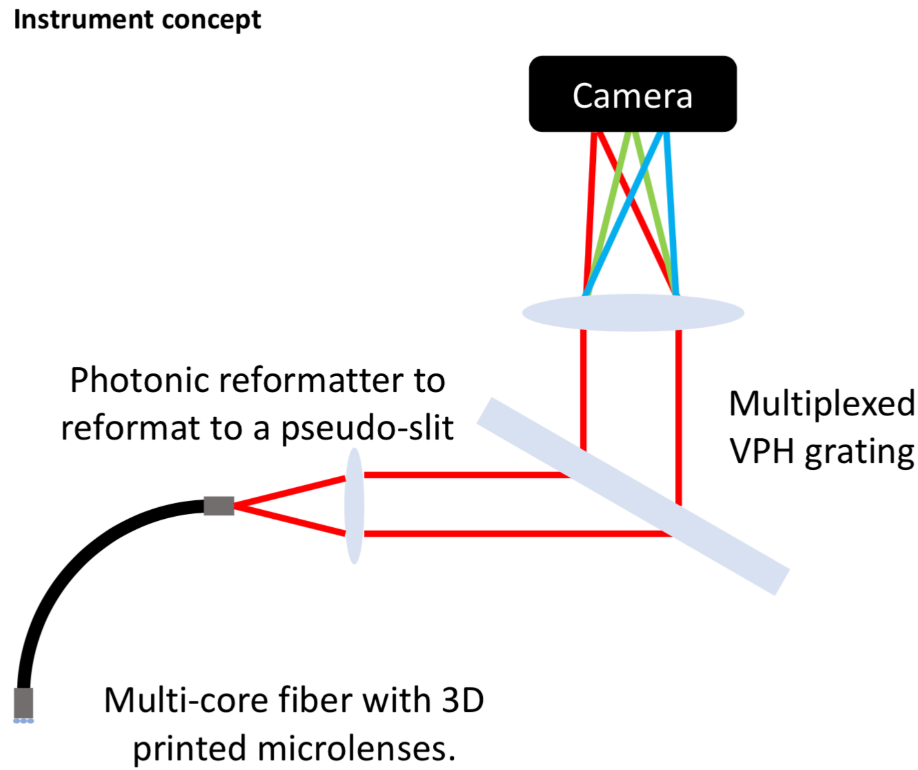
# So then, what is the concept?

Using a multicore fibre

Stacked VPH design

3D printed microlens array

Photonic reformatter



# Spectrograph specifications



So our spectrograph

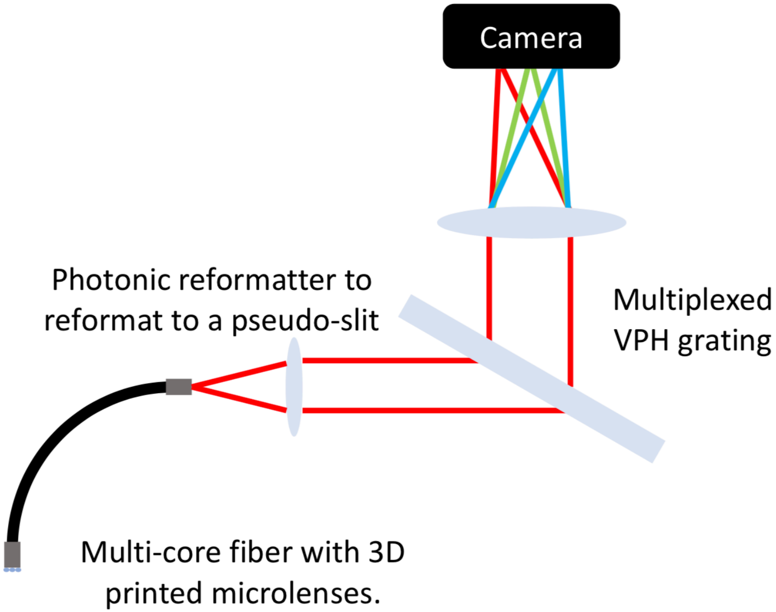
Edges at 1000-1600 nm (1100 -1300 optimised)

R ~ 5000

FOV of ~ 1 arcsecond (at 4.2m WHT)

73 sampling elements (~100 mas at 1.2 um)

**Instrument concept**



# The Fibre

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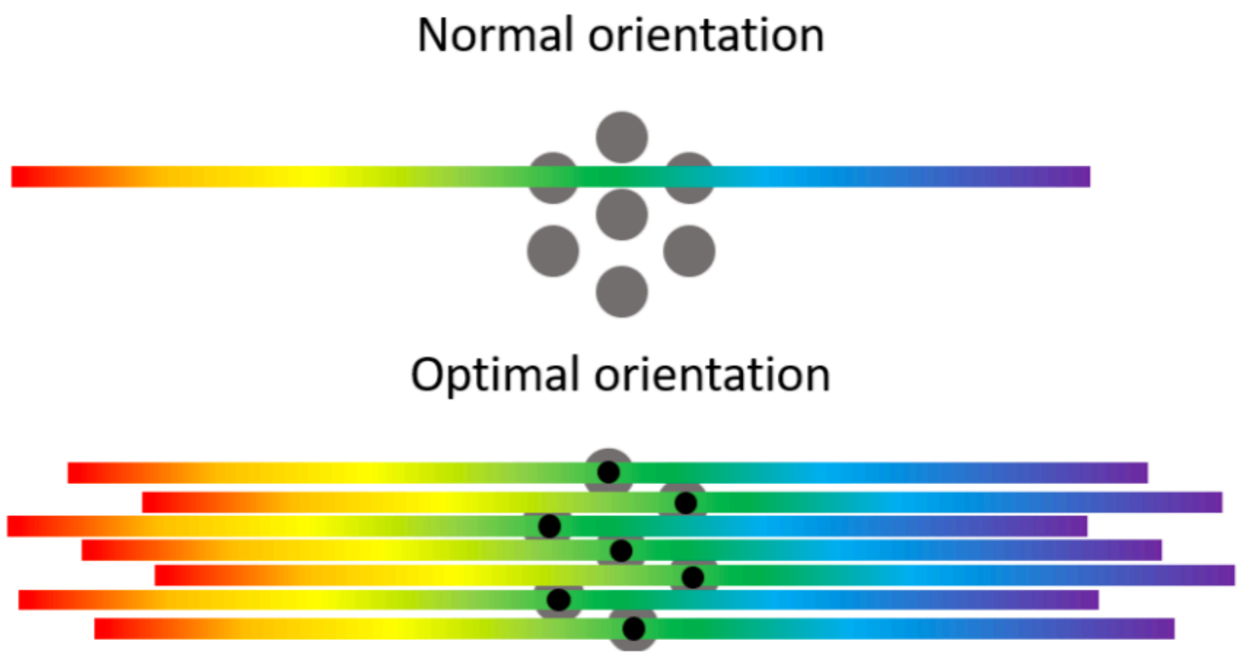
MCF is simpler than using a fibre bundle

Want a fibre with as many cores as possible (larger FOV)

However with more cores dispersion becomes more difficult

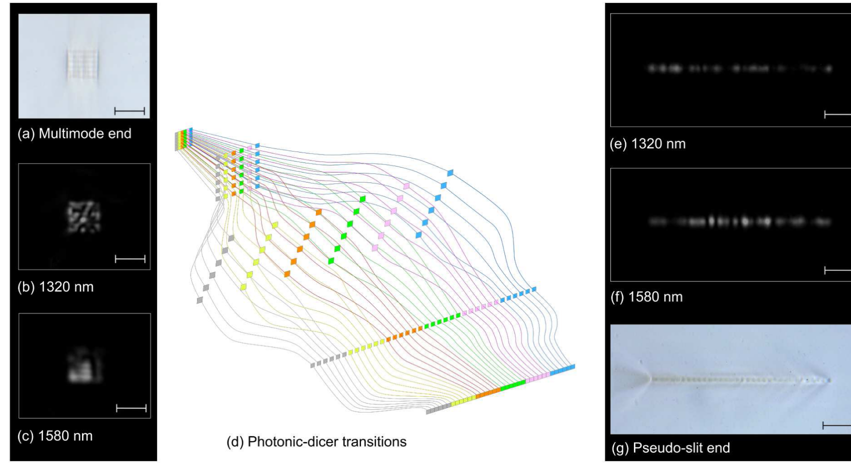


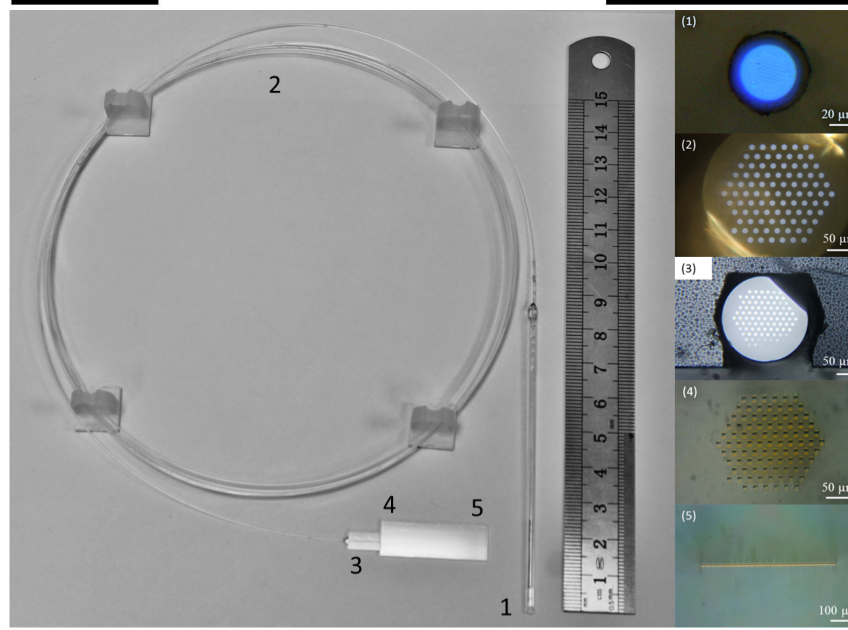
# Reformatter

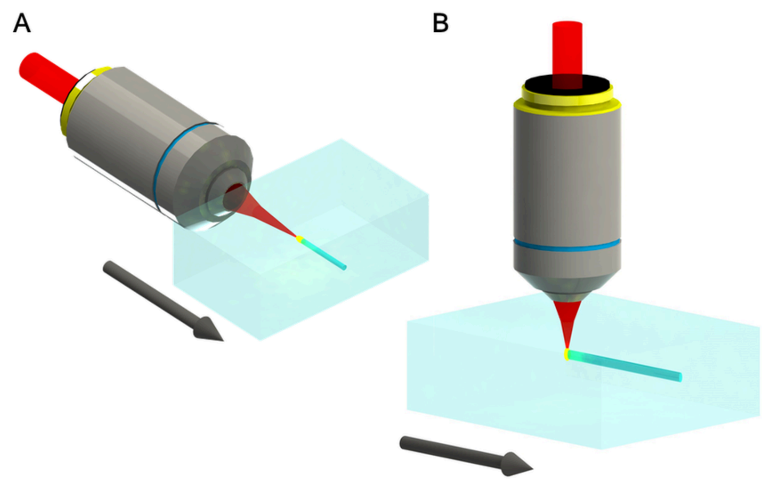
We want to increase the spacing between cores

Use a reformatter created using Ultrafast Laser Inscription

Always at the cost of light



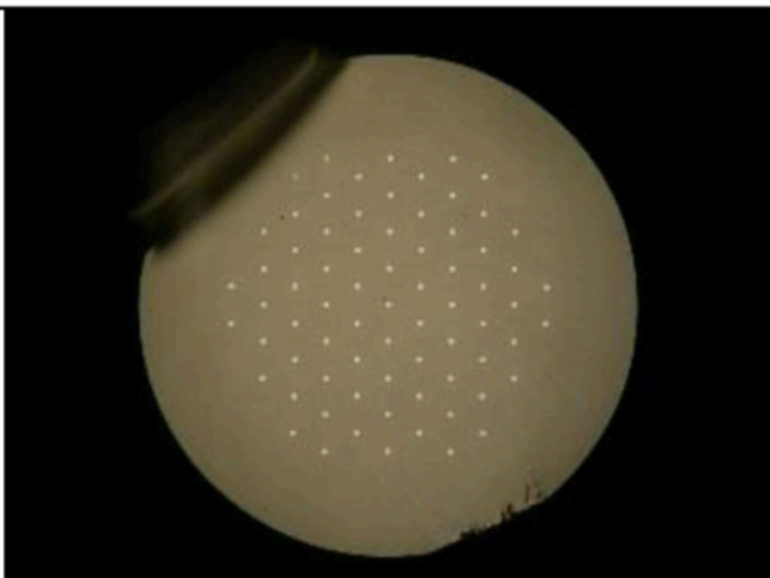
# Fibre

Want sufficiently good sampling

We need a fibre with uncoupled cores (also for reformater)

Luckily I know a guy who makes fibres…..

This is the best pre made fibre



**GIANO**

$N = 73$

$\mathrm{NA} = 0.14$

$d_{core} = 5.3?\ \mu\mathrm{m}$

$\Lambda = 41\ \mu\mathrm{m}$

$D_{outer} = 560\ \mu\mathrm{m}$

$\lambda_{co} = 970?\ \mathrm{nm}$

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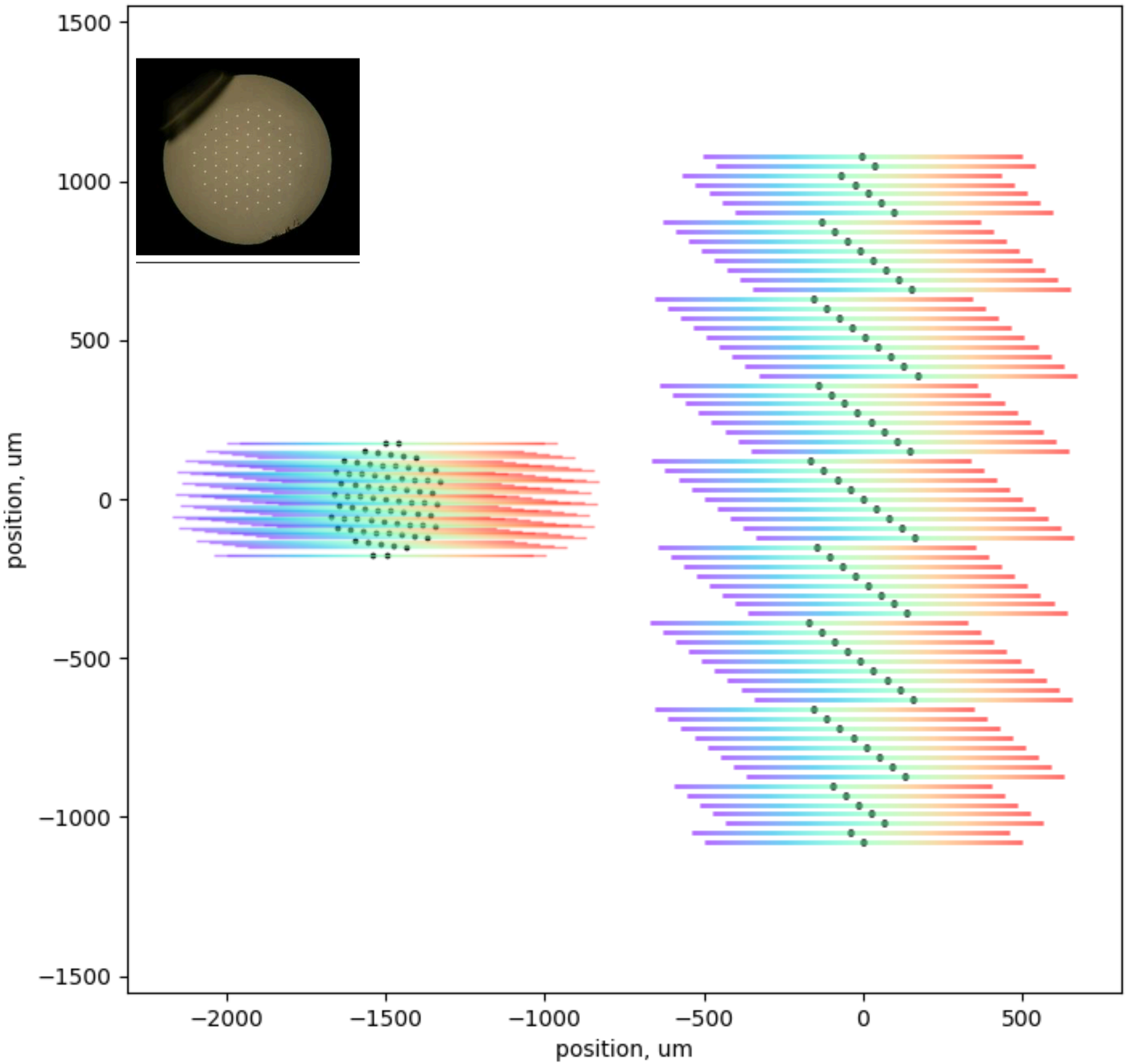
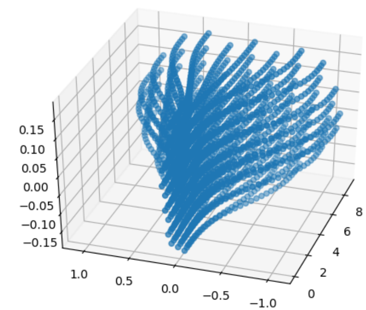


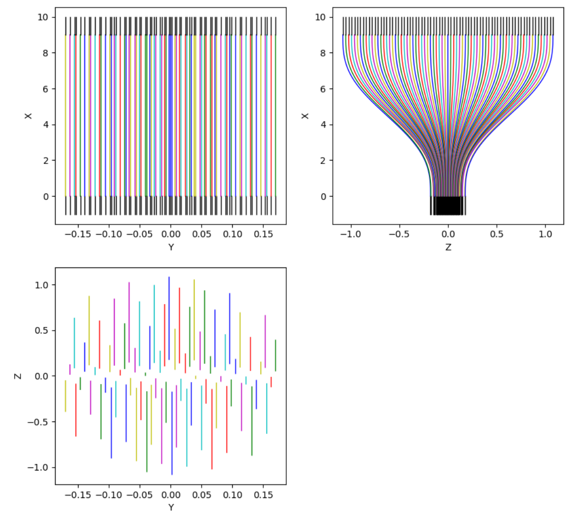



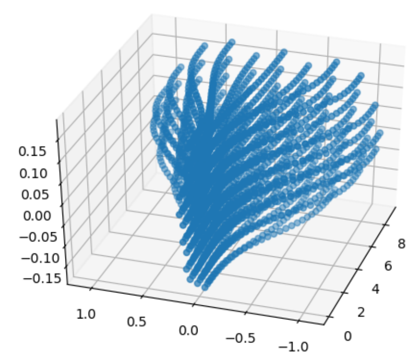
# ULI creation

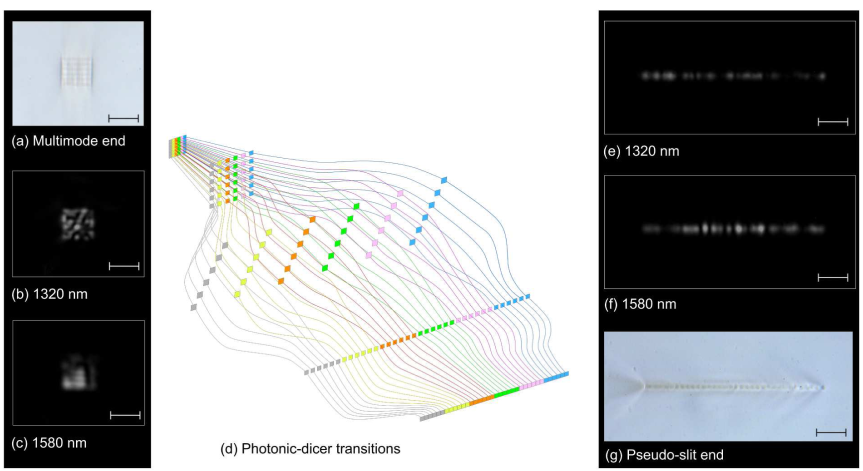
Optimised using Beamprop

Then code written out to G-code

Then given to Heriot-Watt to manufacture





# Scattering removal

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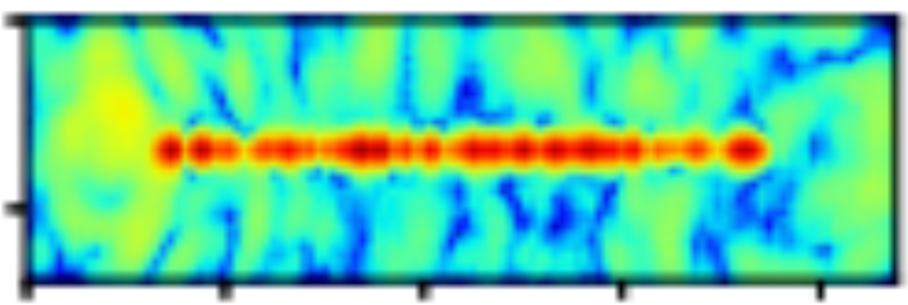
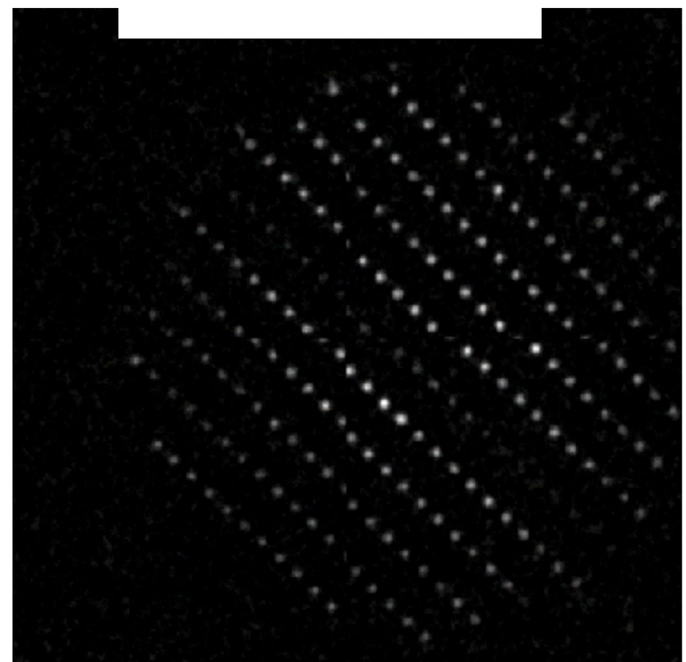
One of our worries in the system is stray light

Try to reduce it by placing a mask at the output of the reformatter

Exact details to be decided





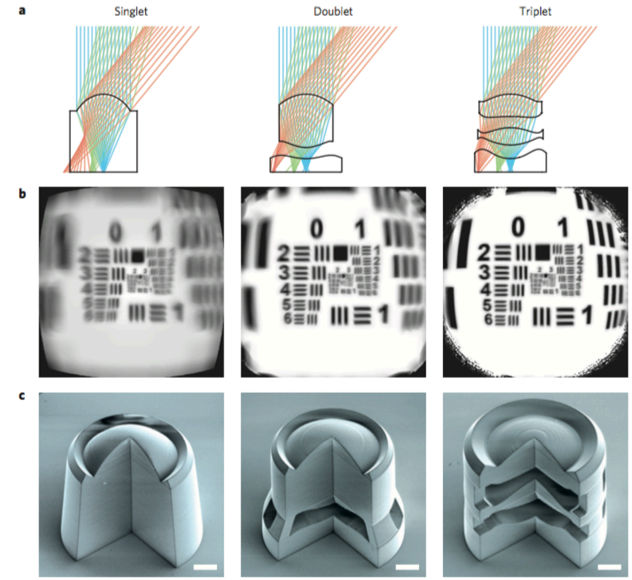
# Microlens array

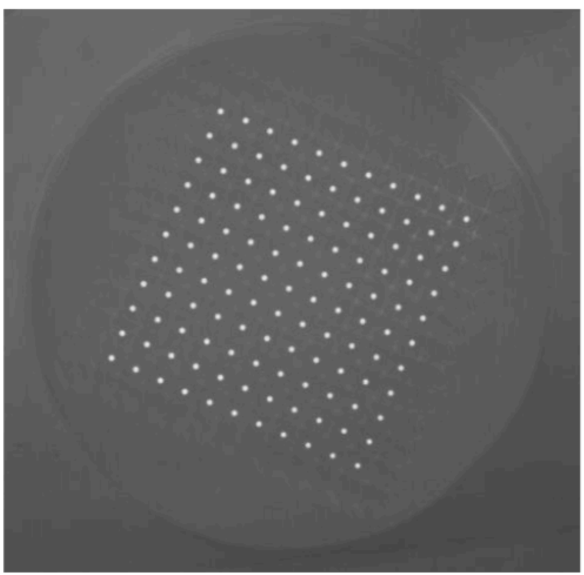
Want to couple light in efficiently

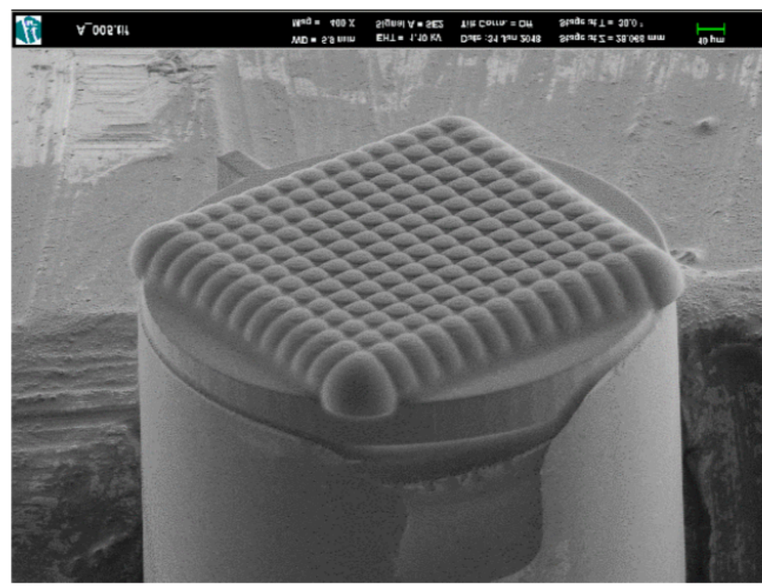
Use a 3D printed microlens array

Customisable

Easy alignment



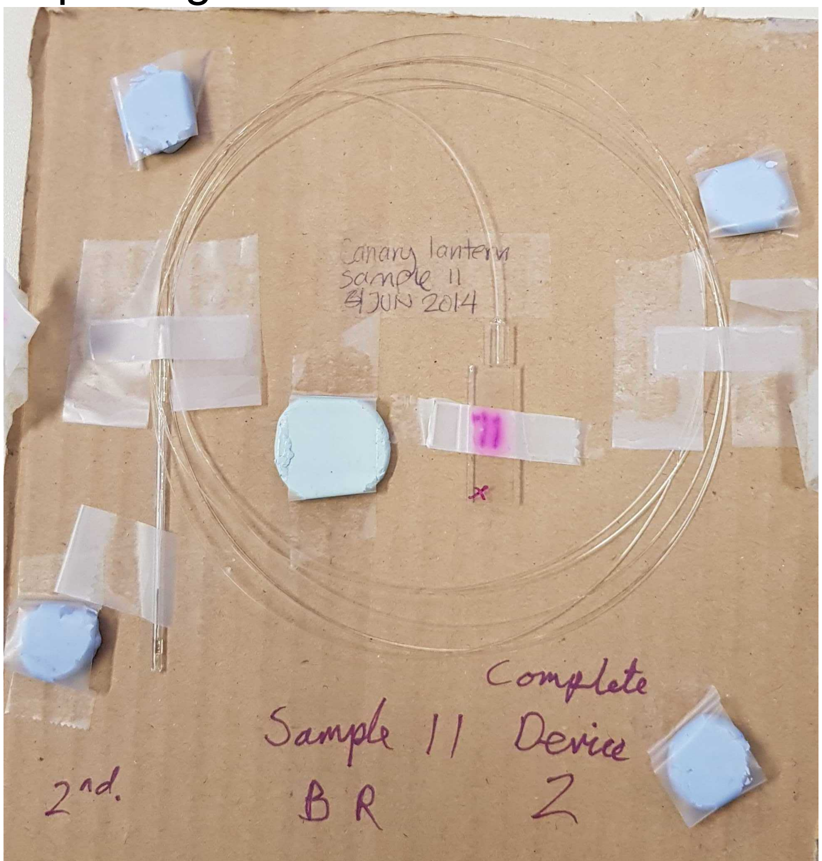



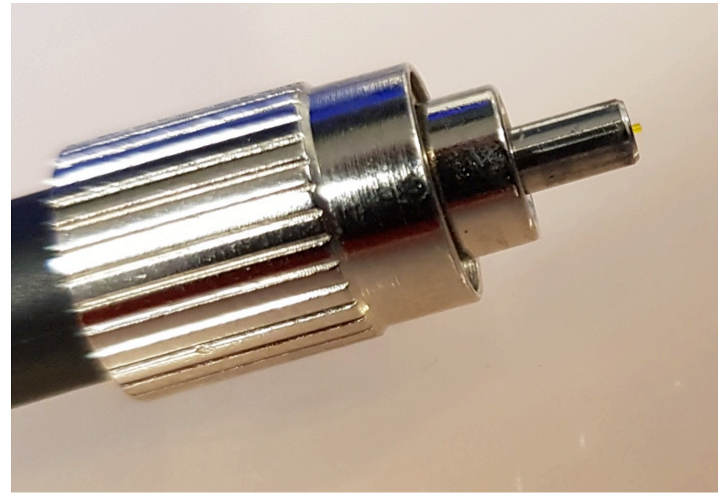


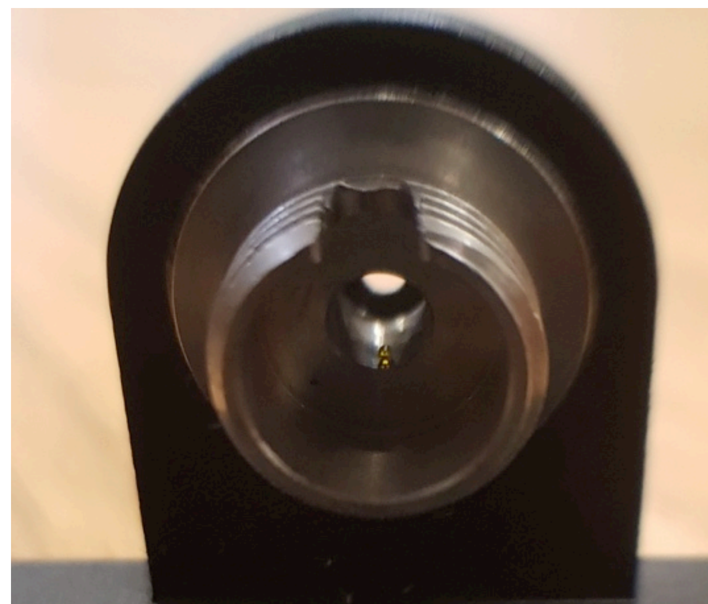
# Packaging

As with all fibres our components are fragile

Our components are also custom, so we need to package them somehow





# More 3D printing

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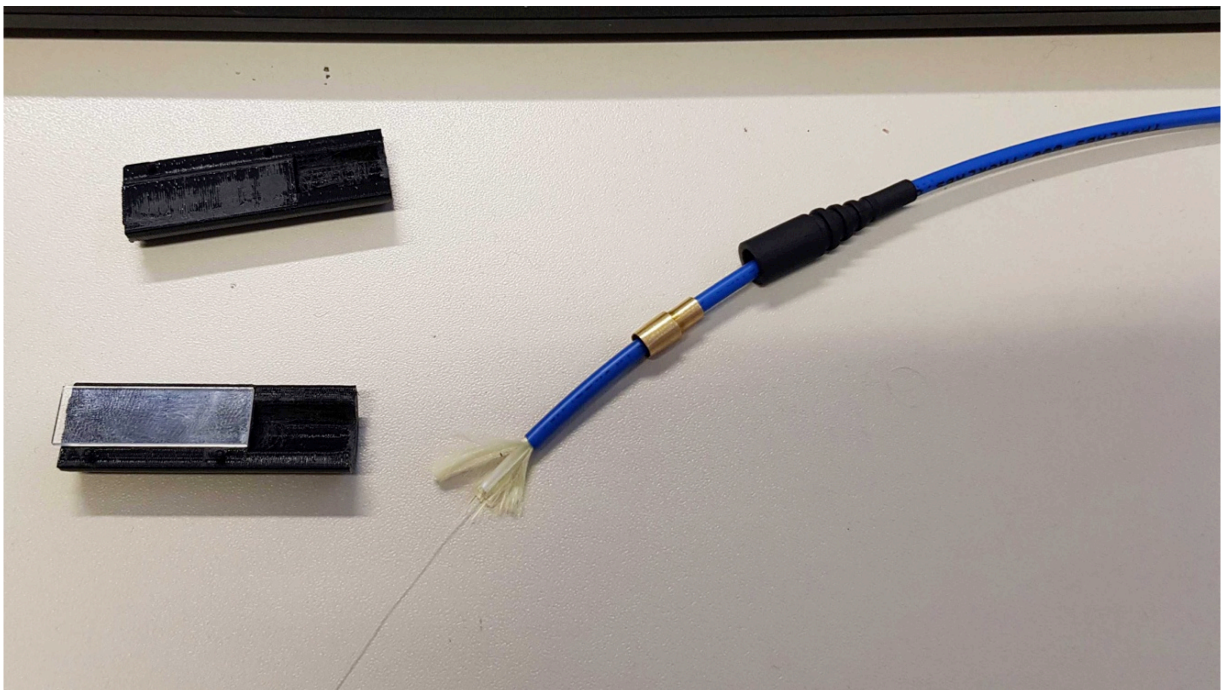
All our parts are custom, so difficult to find standard parts

Chatted to Santiago Barboza

He and Norbert Münch helped design and print



# Packaging

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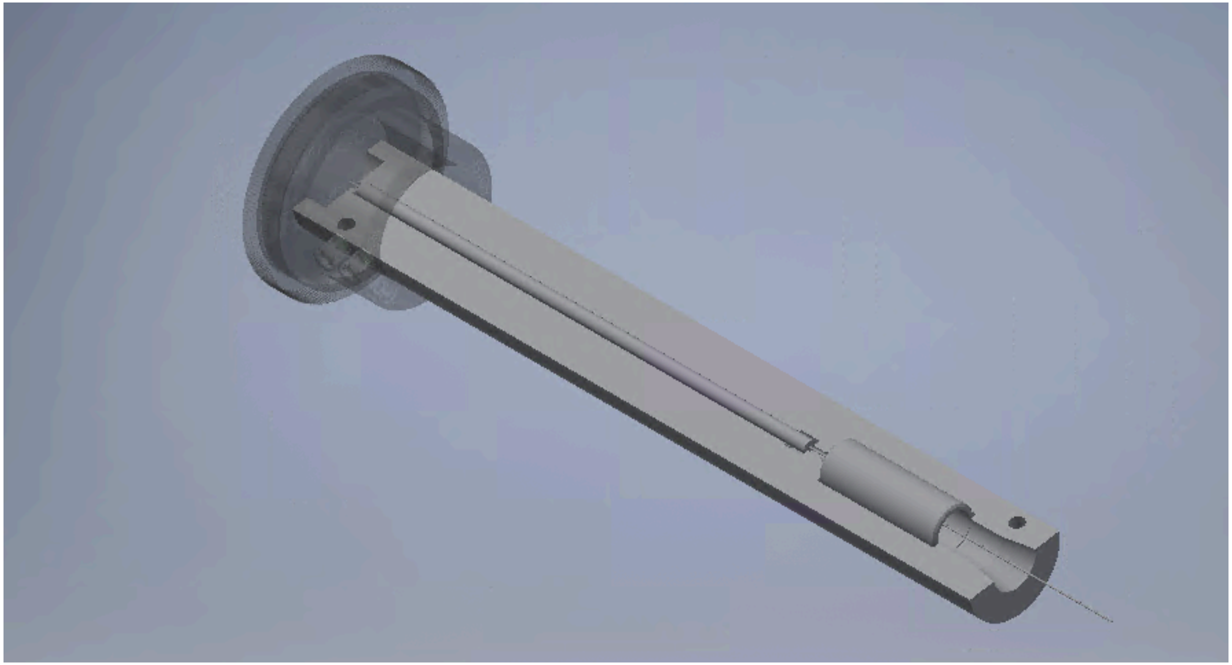
After a few attempts…

Decided on metal furcation tubing (crush resistant)

Thorlabs parts and 3D printed parts.

Prototype done!



# Spectrograph optics

Quite simple really:

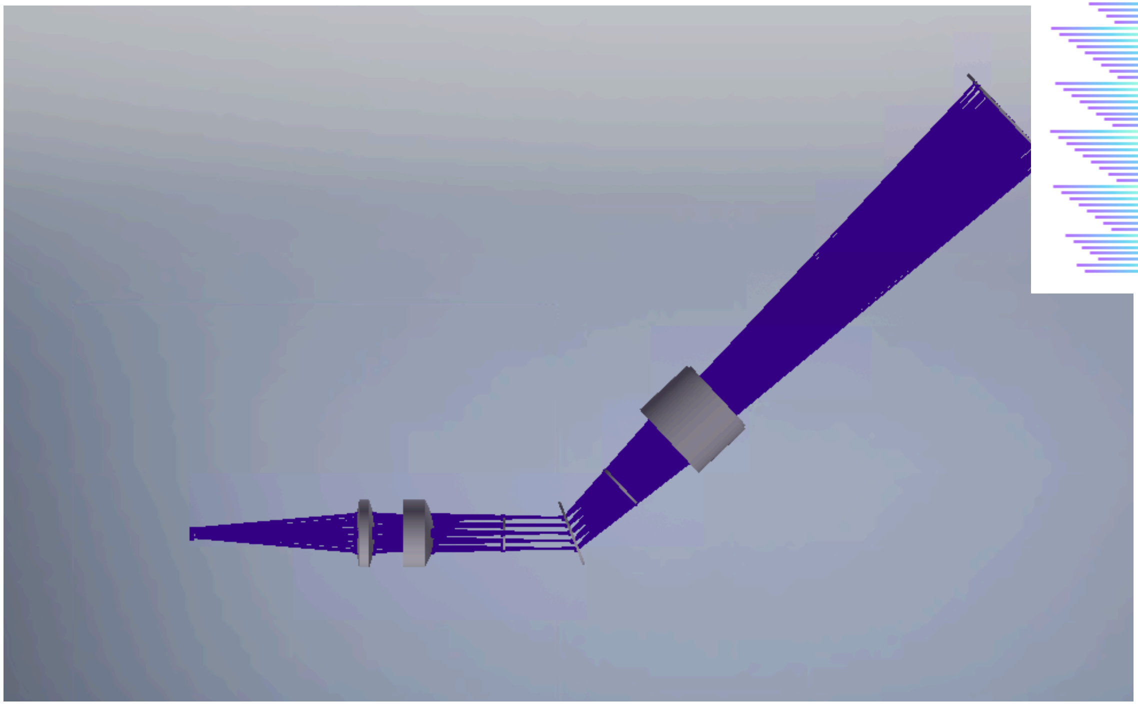
Chip input

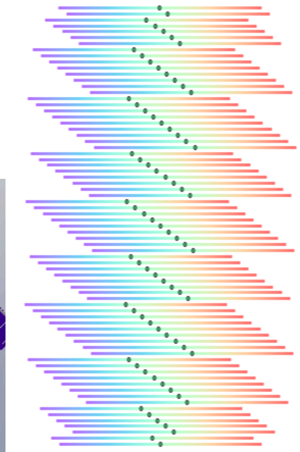
Two singlet lenses

VPH grating

Thorlabs lens

Camera





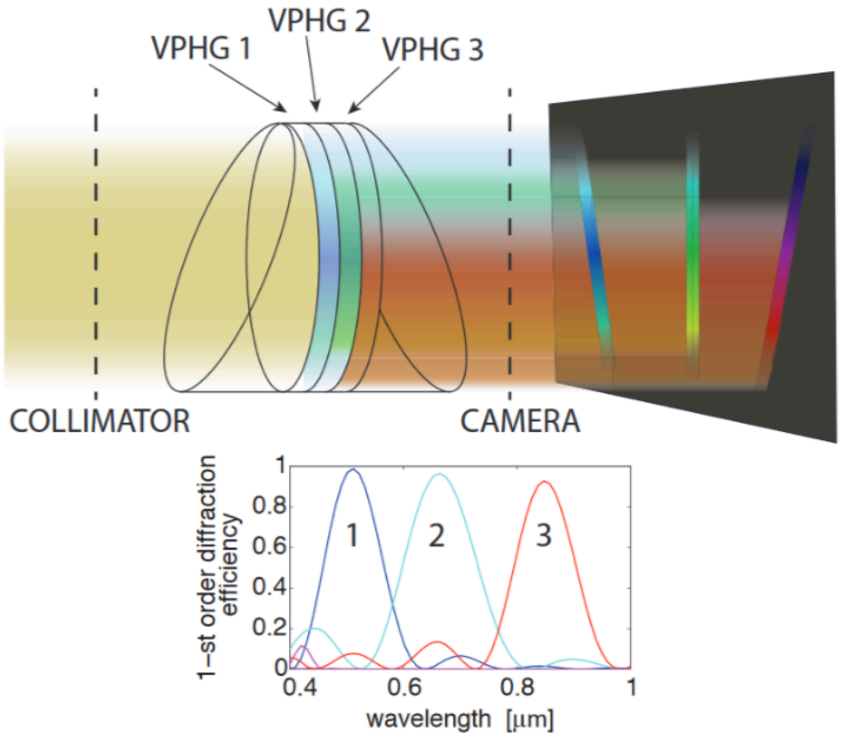
# VPH grating

Created by group in Milan

Good as they are WP7 of OPTICON

Novel 3 layer design

Broadband, but lower efficiency as stacked



# Camera

Using C-RED-2 from NAIR grant

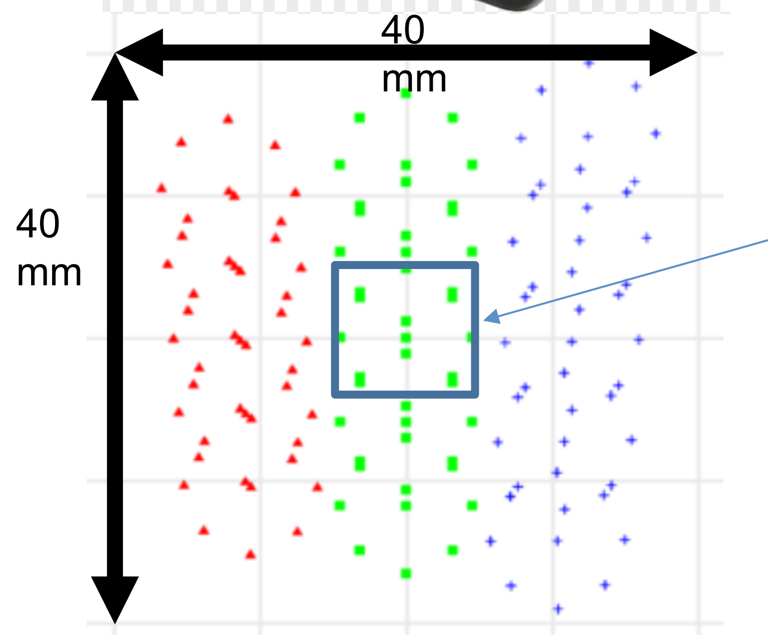
512x480 pixels

Water cooled

30e- rms read out, low dark (for InGaAs), but still not perfect

Automated scanning in one direction

Manual in the other



# Calibration

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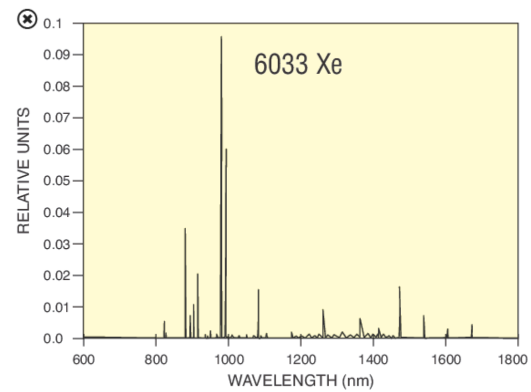
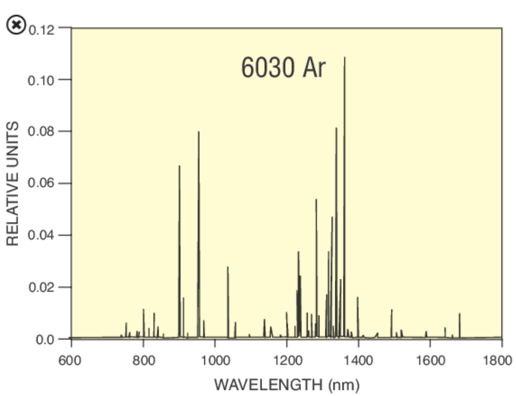
We will use spectral lamps for calibration

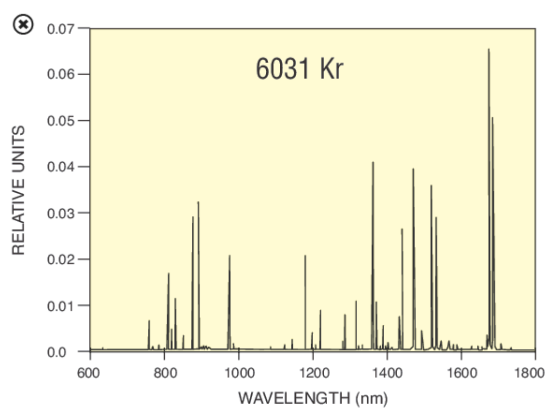
Have access to Argon, Krypton, Neon, Xenon

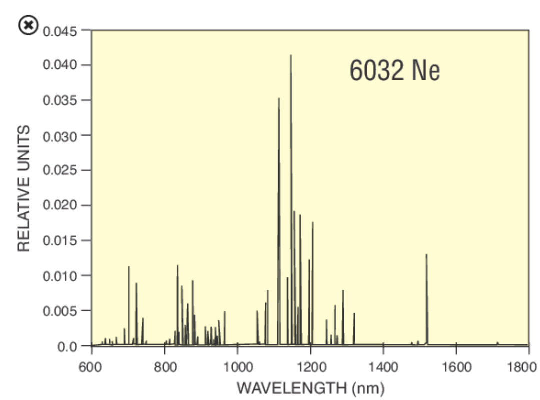
Ideally we would like a better system, but this will do for now

Better than Telluric lines….



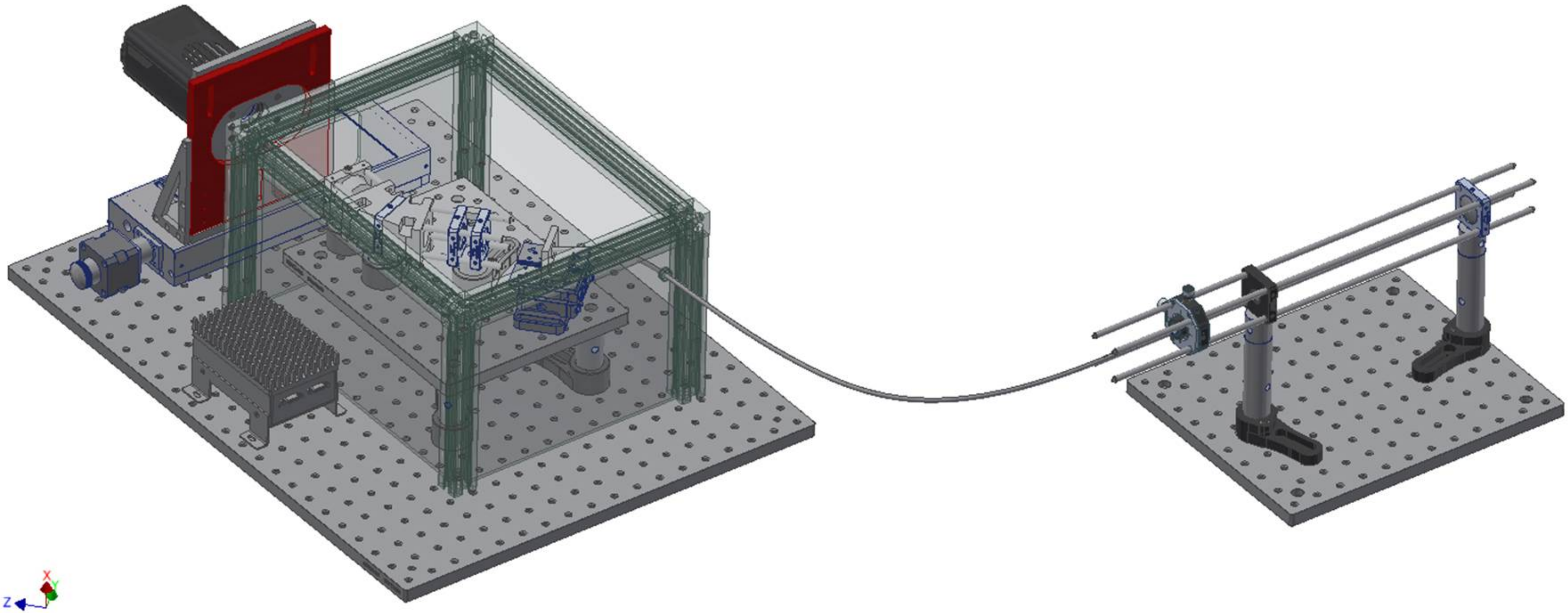



# Mechanical Design

Being done by Edoardo Redaelli

Mostly stock parts, so quick and easily assembled



# CANARY

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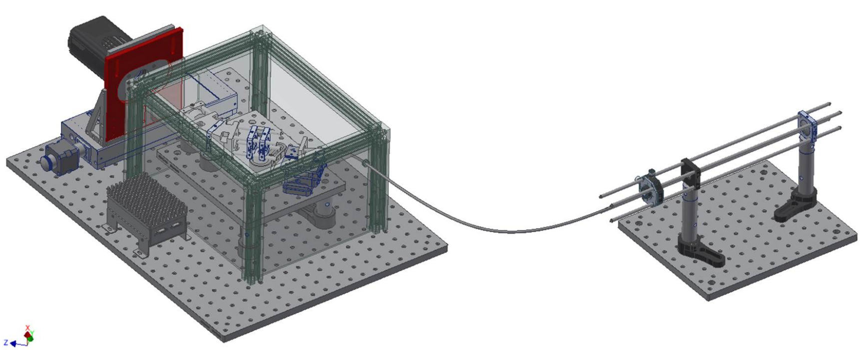
Ideally we want to use with XAO system

Need to prove technology first

Granted time on CANARY (July)

Strehl of around 30% in H band..

Will use it in SCAO mode



# End to end Throughput

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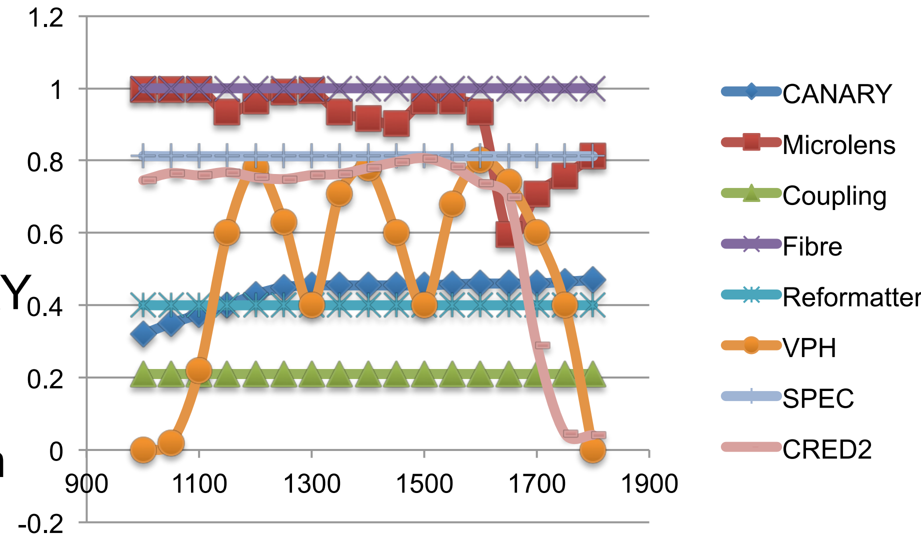
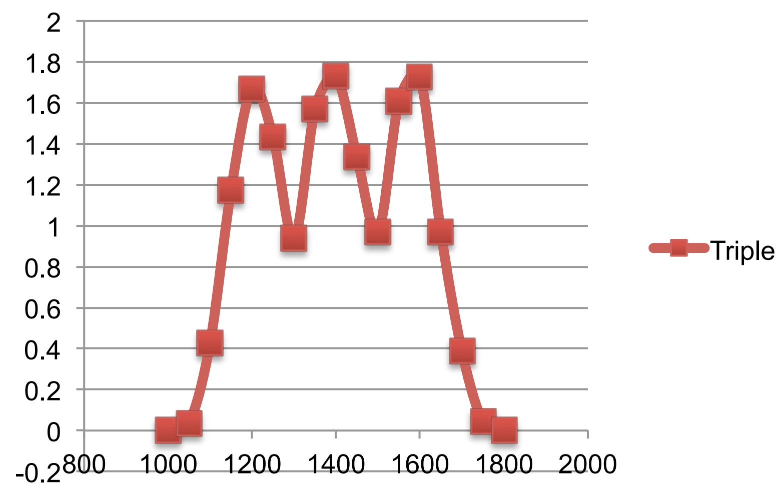
End to end throughput estimated at just under 2 %

Losses mainly in fibre coupling, CANARY and reformatter (estimated)

Should ideally be around 10 % total with XAO system

Plenty of room for future improvement with a more suited system.



# Our aims

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Unachievable plan : Go on sky, take a few spectra of boring stuff, realise we've got 200% throughput, get spectra of known planetary systems, with our 20 minutes of spare time find two new planetary systems. Win various prizes.

Ideal plan : Go on sky, take a few spectra of standard stars. Take some spectra of extended objects/binaries. Move onto known planetary systems, manage to get at least one spectra, prove our concept works and publish the spectra of the planet. Get fancy paper

Likely plan : Go on sky, take a spectrum of a star, prove we get light in. Get some close binaries/extended objects and show that we can see them, try to get a spectra of a planetary system, realise we can't do it due to contrast/light problems.

If it all goes wrong : We get no light, everything fails (for one of many reasons). Cry/Pub?

# The future

Unless we are lucky we won't change the word with our test

But we should get some good results

We then want to improve our system and test with XAO and coronagraph

So we smile sweetly and get time on a larger telescope

# Conclusions

We are building a Multi-core fibre fed integral field unit

It combines everything I do, plus extra stuff

Testing at the William Herschel Telescope in July

Hopeful for the future

**Instrument concept**