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Infrared transmission gratings manufactured using ultrafast laser inscription

David Lee and Colin Cunningham, STFC, UK ATC.

David MacLachlan and Robert Thomson, Heriot-Watt University.

Helen Butcher, Richard Brownsword, and Damien Weidmann, STFC, RAL Space.

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UK Astronomy Technology Centre

HERIOT WATT UNIVERSITY

RAL Space

Introduction

- Scientific motivation.
- Overview of Ultrafast Laser Inscription (ULI).
- Advantages of laser inscription.
- Near-Infrared transmission gratings.
- Mid-Infrared transmission gratings.
- Summary and Conclusions.

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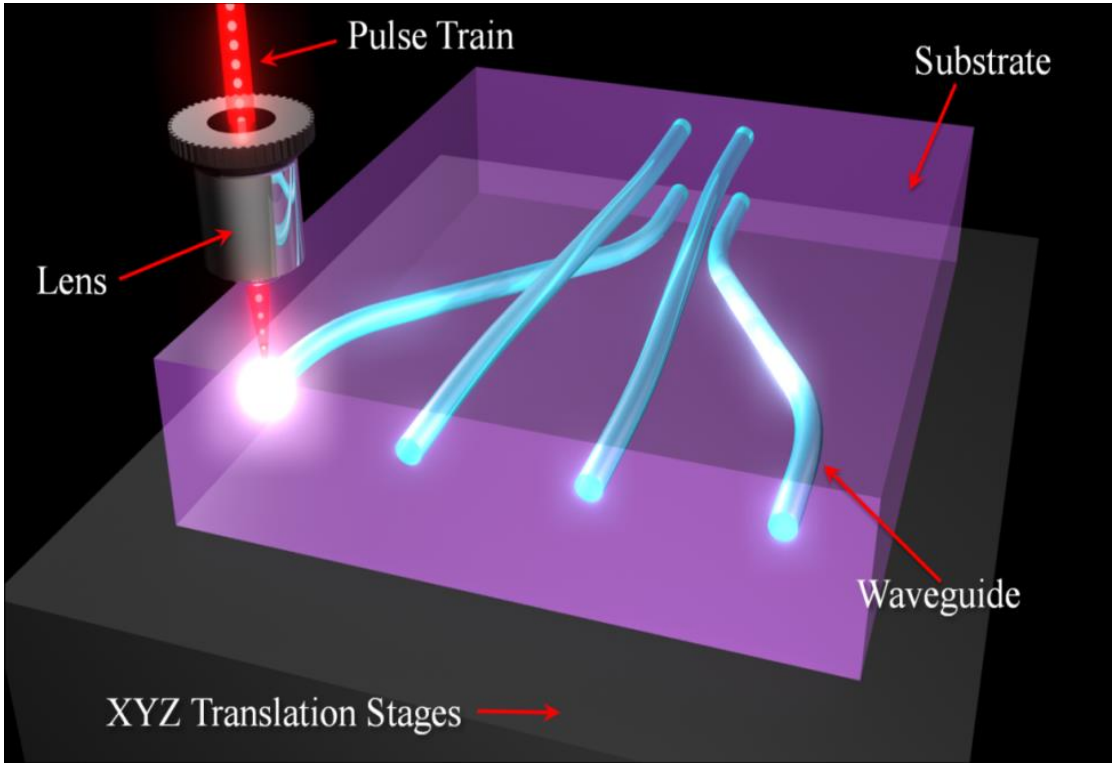
Scientific Motivation

- There is a scientific need for high efficiency transmission gratings that operate at wavelengths above 2.5 µm:
  - Mid-Infrared astronomy.
  - Earth observation.
  - Remote sensing.
- Transmission gratings can provide a more compact optical layout than using mid-infrared reflection gratings.
- Ultrafast Laser Inscription is used for manufacture of near and mid-infrared photonics in a variety of materials.

Ultrafast Laser Inscription



K. M. Davis et al, Opt. Lett. **21**, 1729 (1996)

High peak power laser is focussed within the material.

Refractive index is permanently modified near the focus.

Material is translated to create photonics structures such as grating lines.

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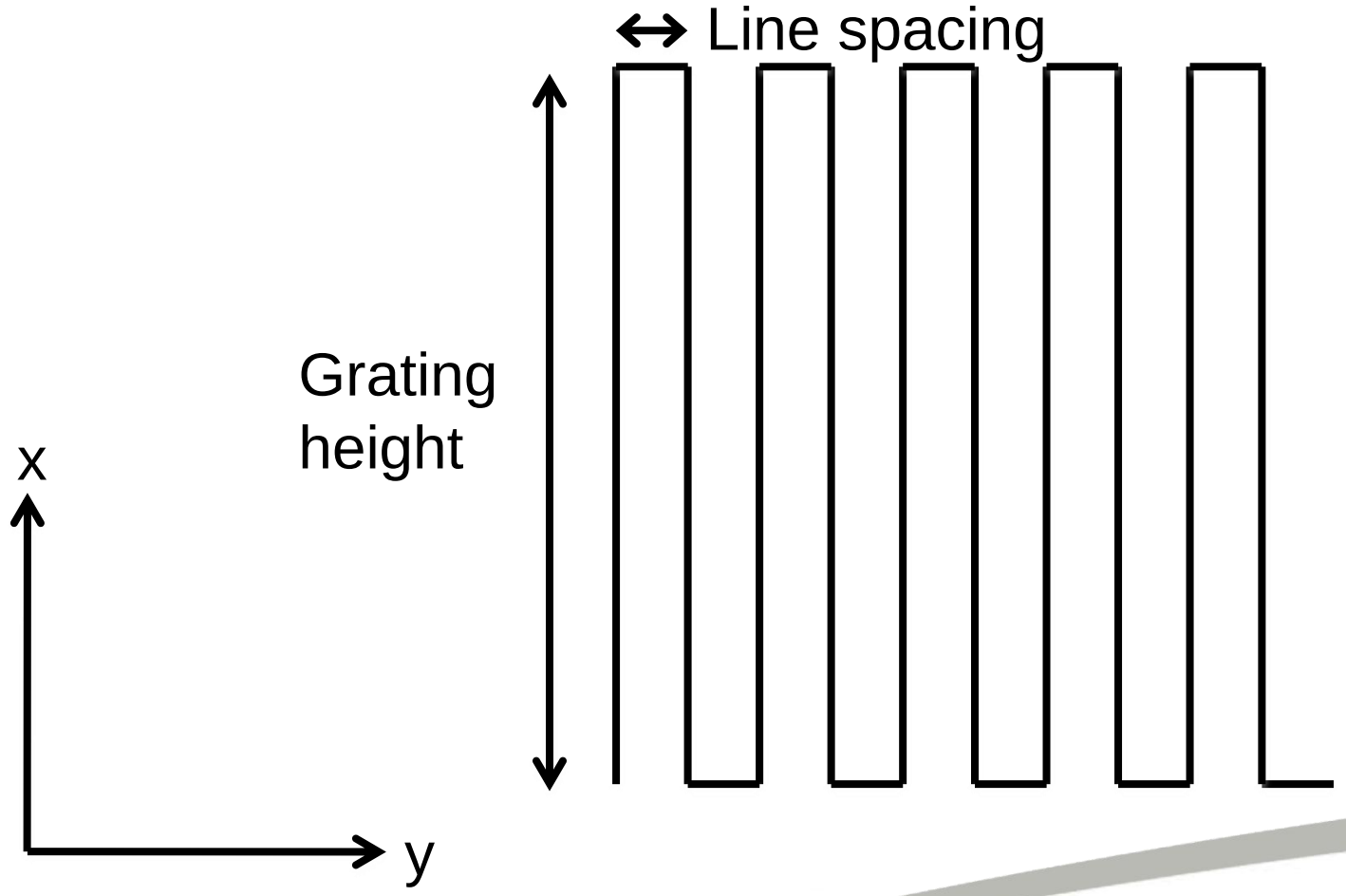
Grating generation using raster pattern



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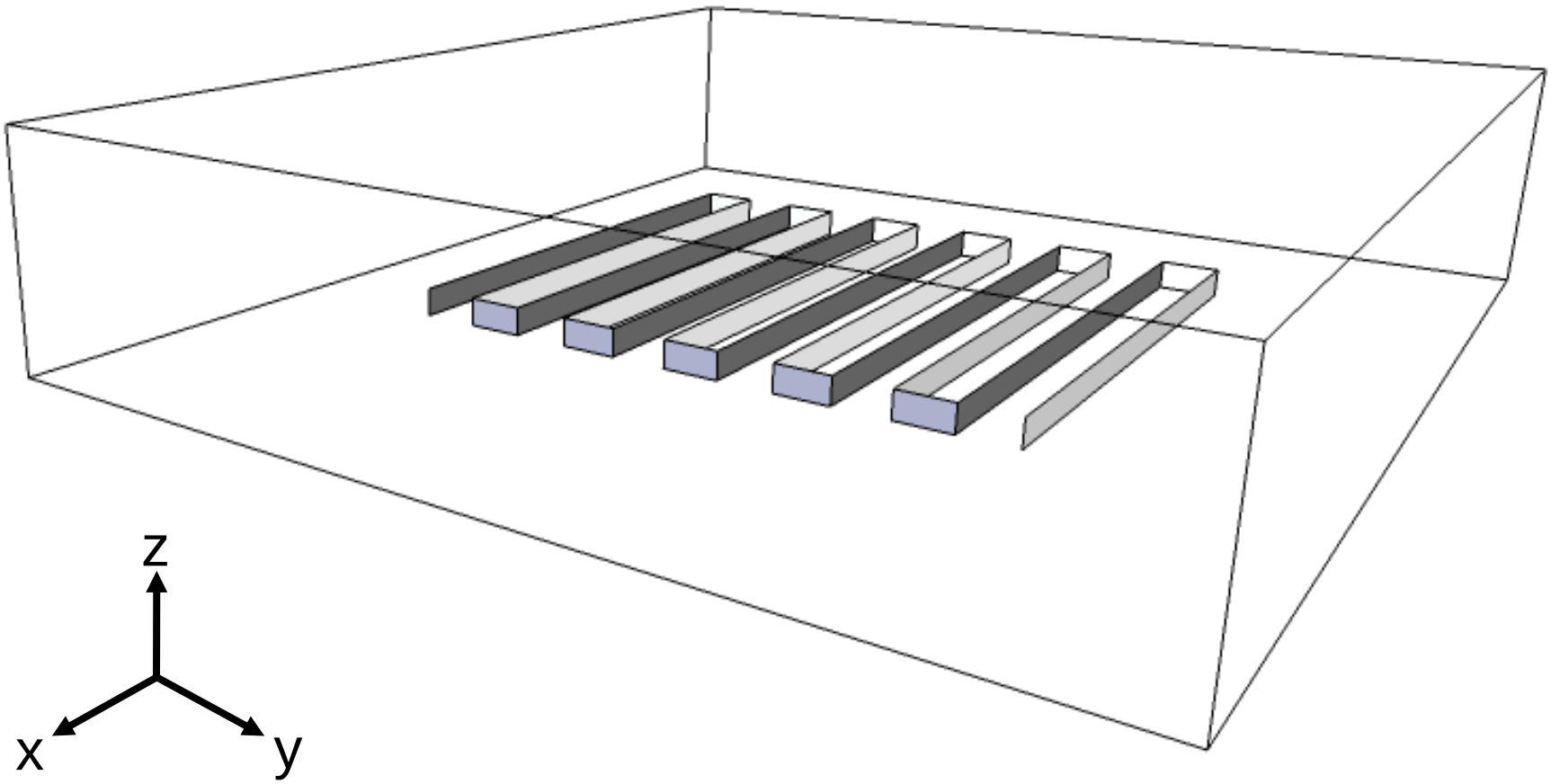
Ultrafast Laser Inscription of a Grating



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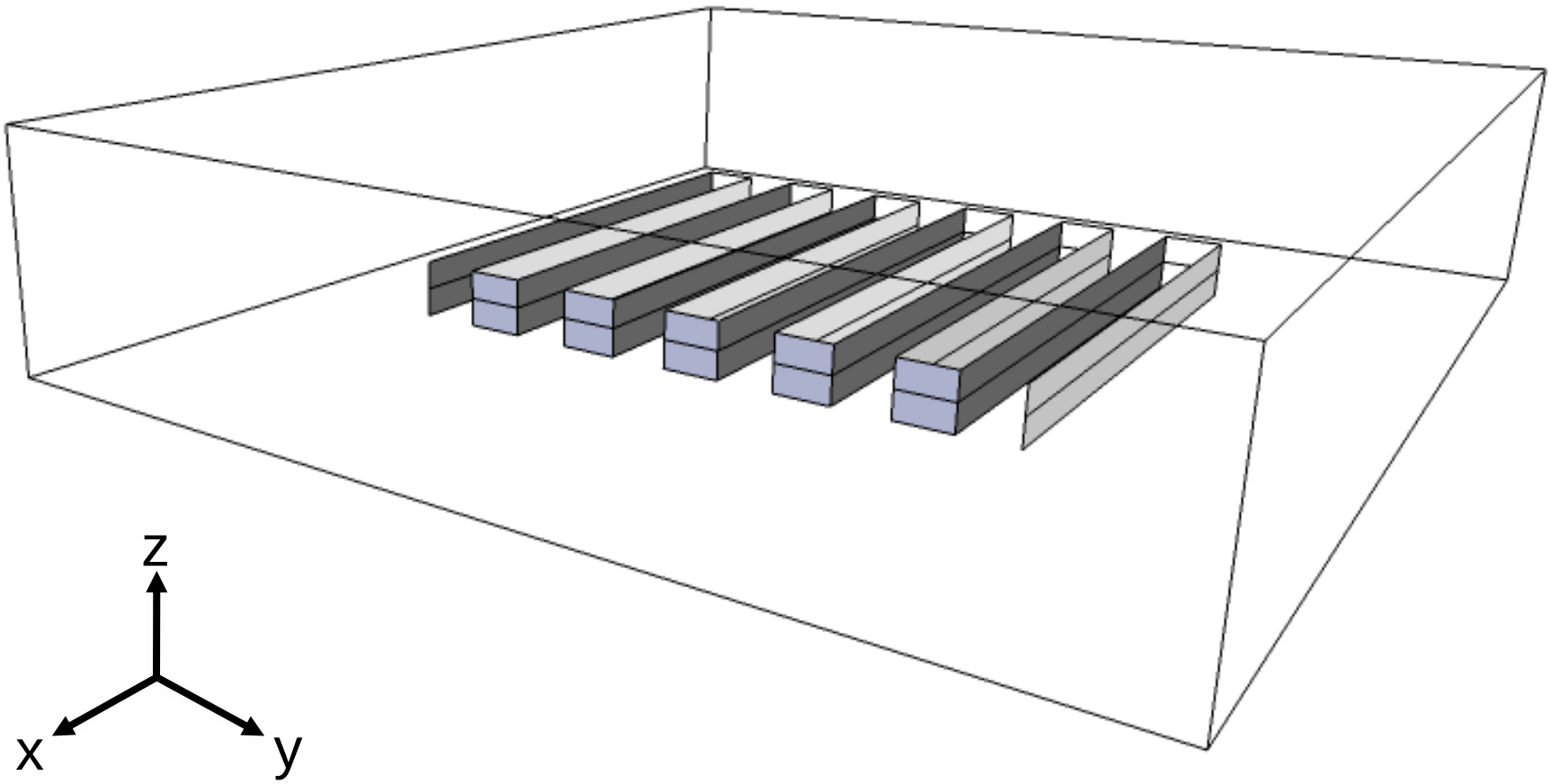

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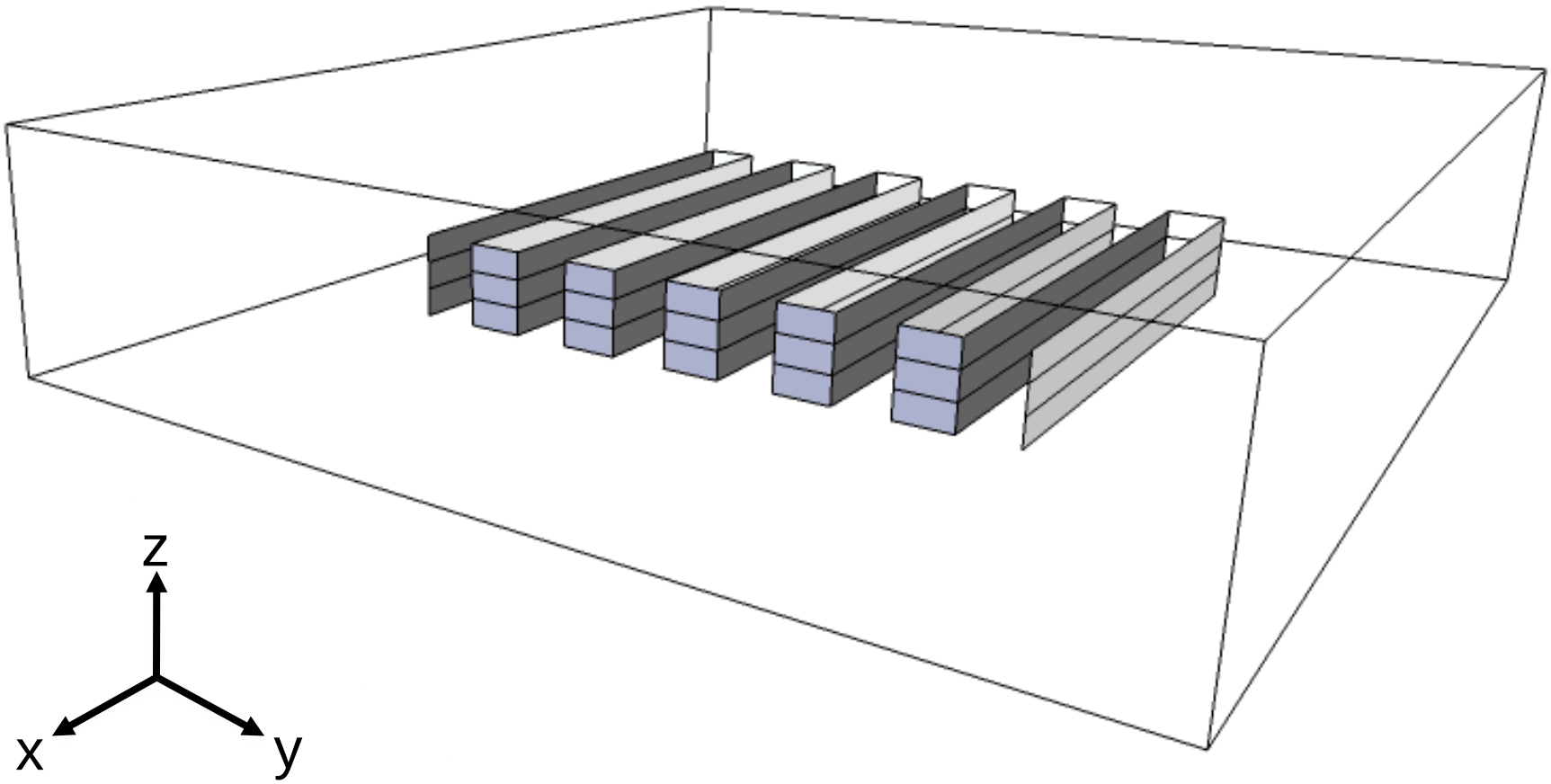
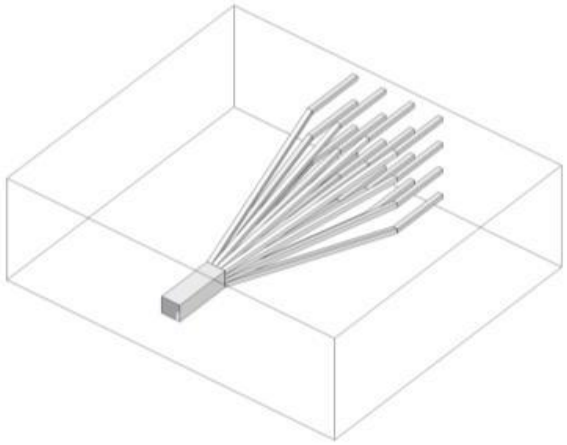
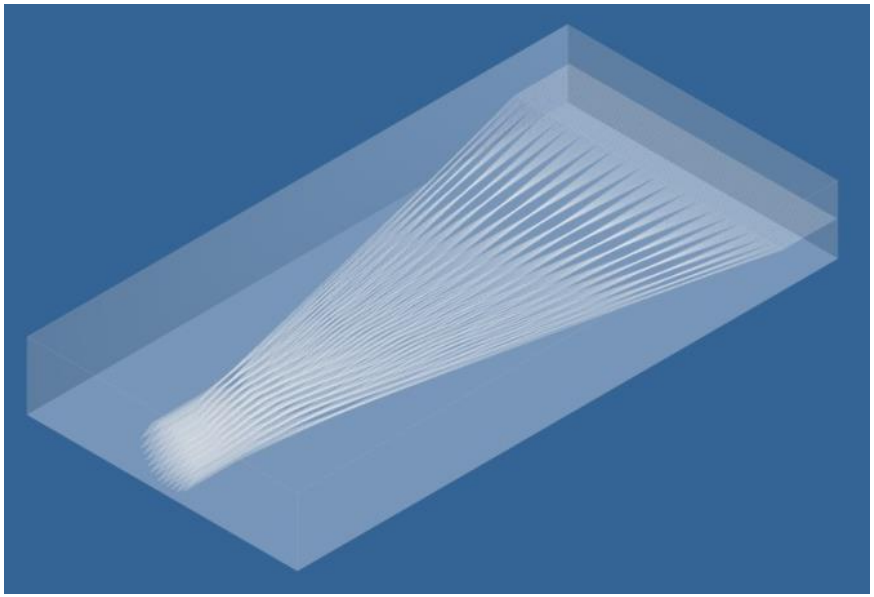


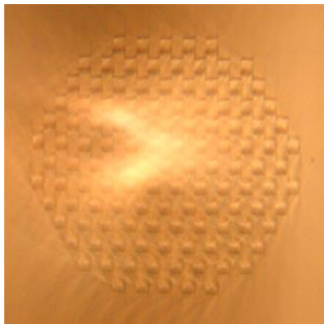
ULI – Advantages

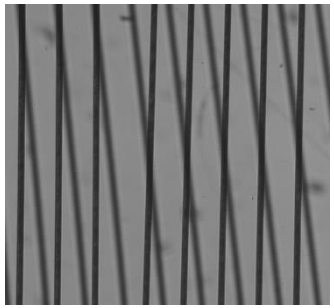
- Gratings can be made in many different materials.
- Laser inscription enables complex custom grating shapes, for example non-straight lines or slanted profiles.
- A number of photonics structures can be combined within a single substrate.
- High efficiency.
- Very Robust.

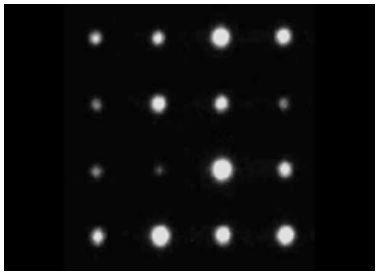
Photonics Devices

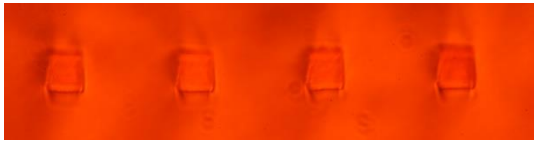












Example ULI fabricated integrated photonic lanterns for multimode-to single mode conversion

Reference: R. R. Thomson, et al, Opt. Express **19**, 5698-5705 (2011)

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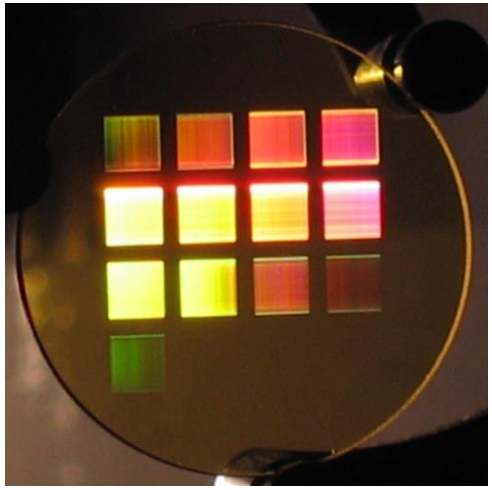
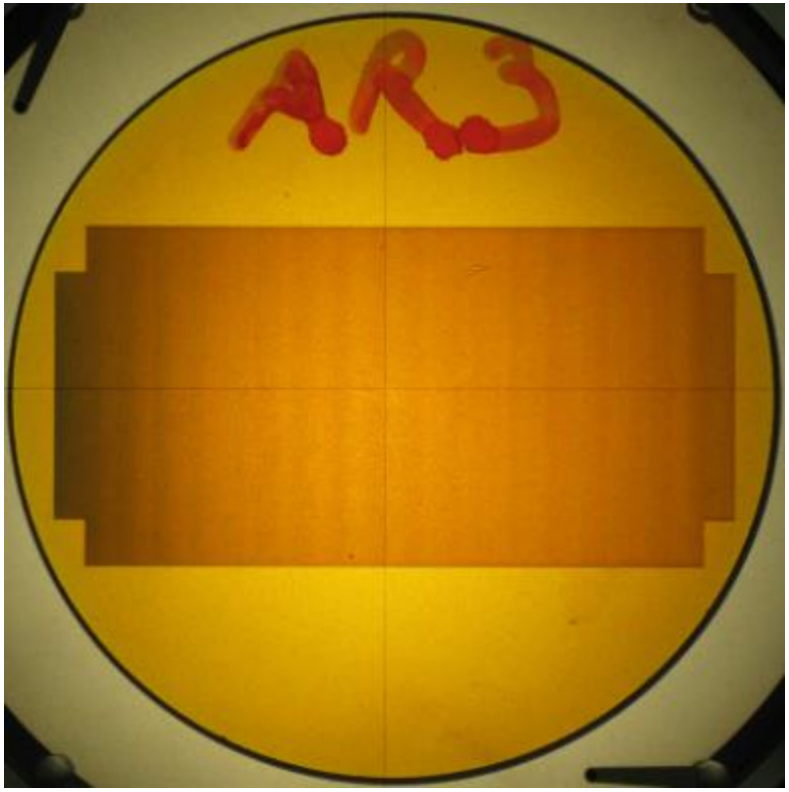
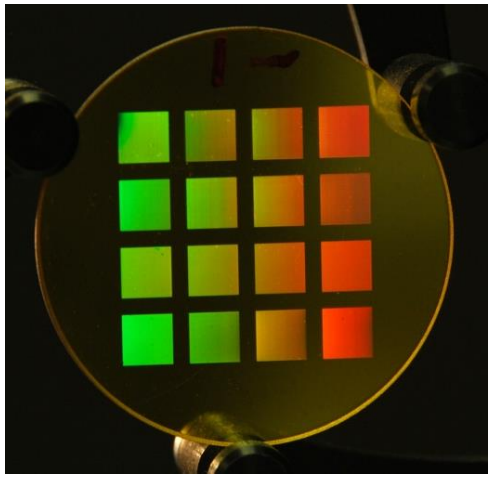
Near-Infrared ULI Gratings







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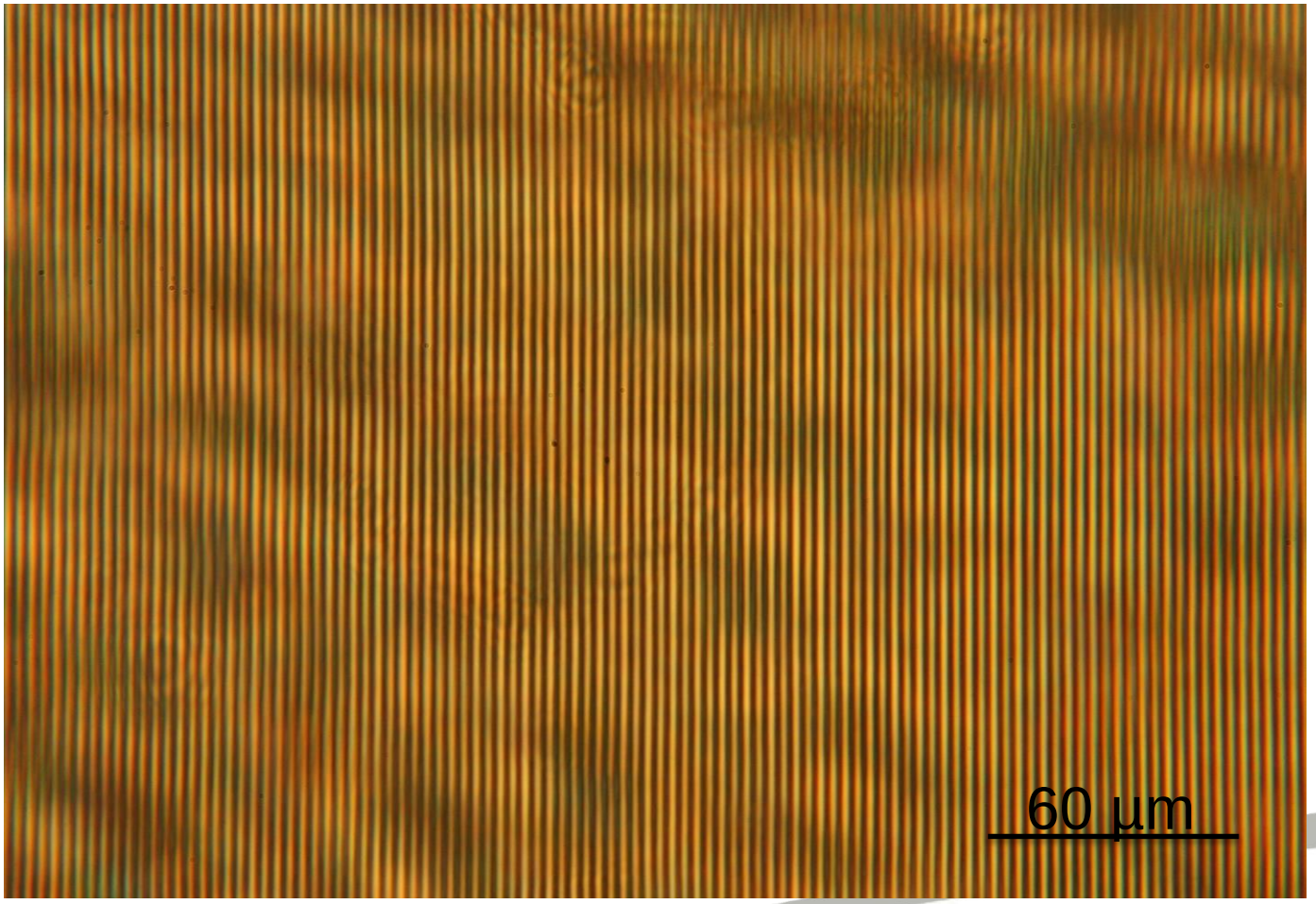
Magnified View of Grating Structure



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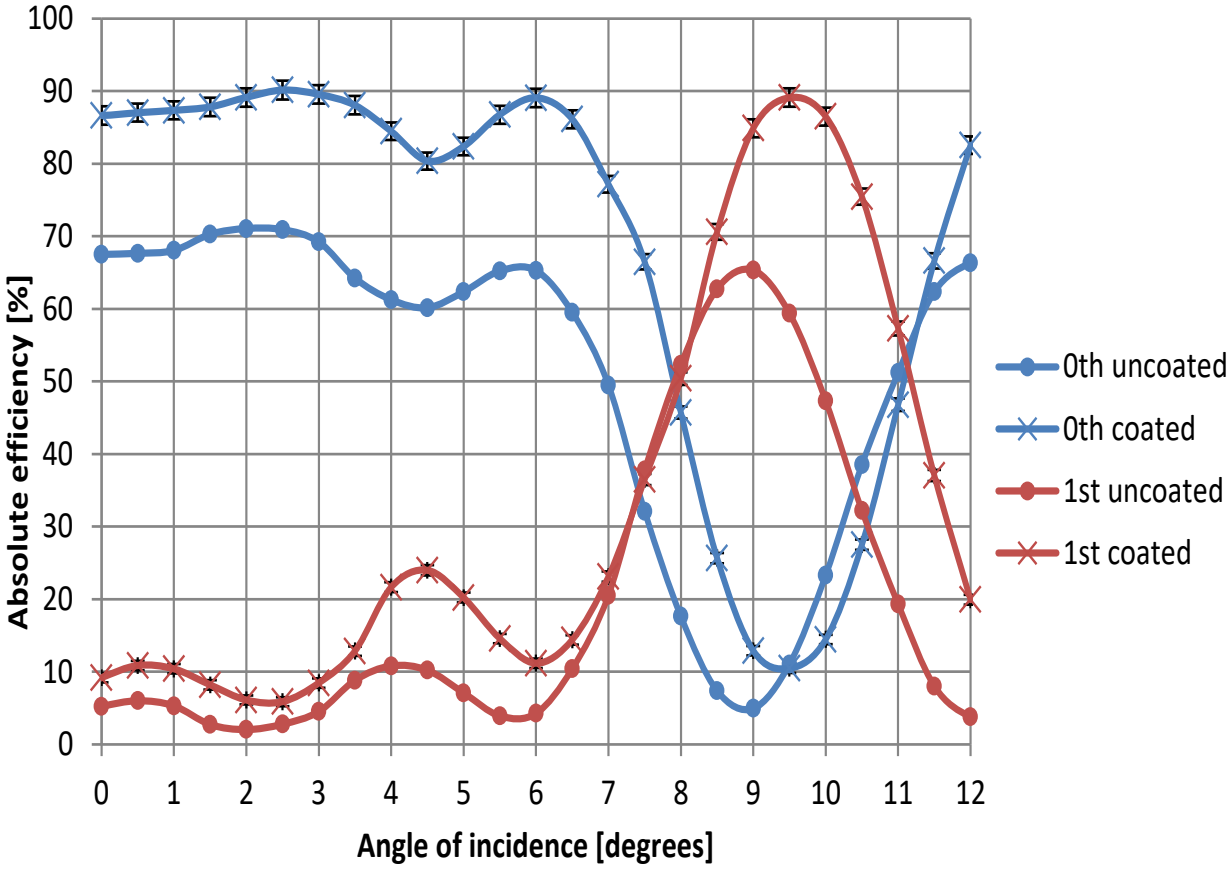
Near-Infrared Efficiency Results



Efficiency measured at 980nm

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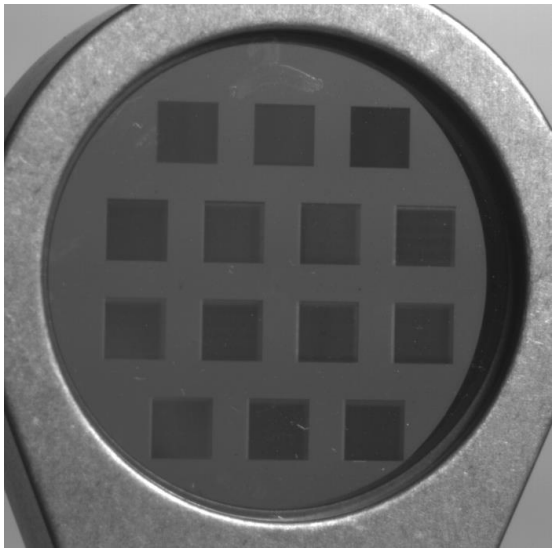
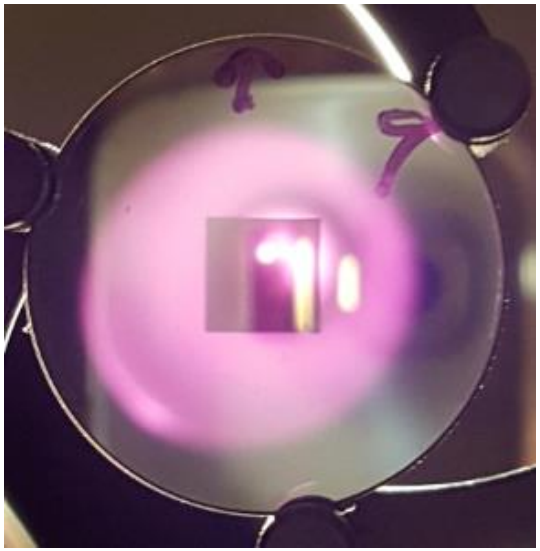
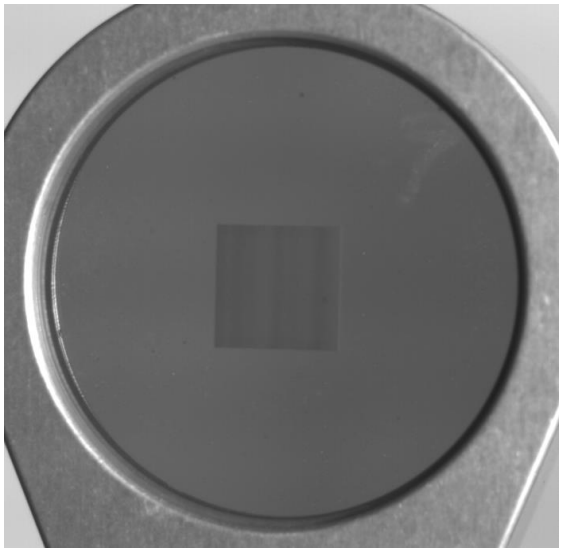
Mid-Infrared ULI Gratings

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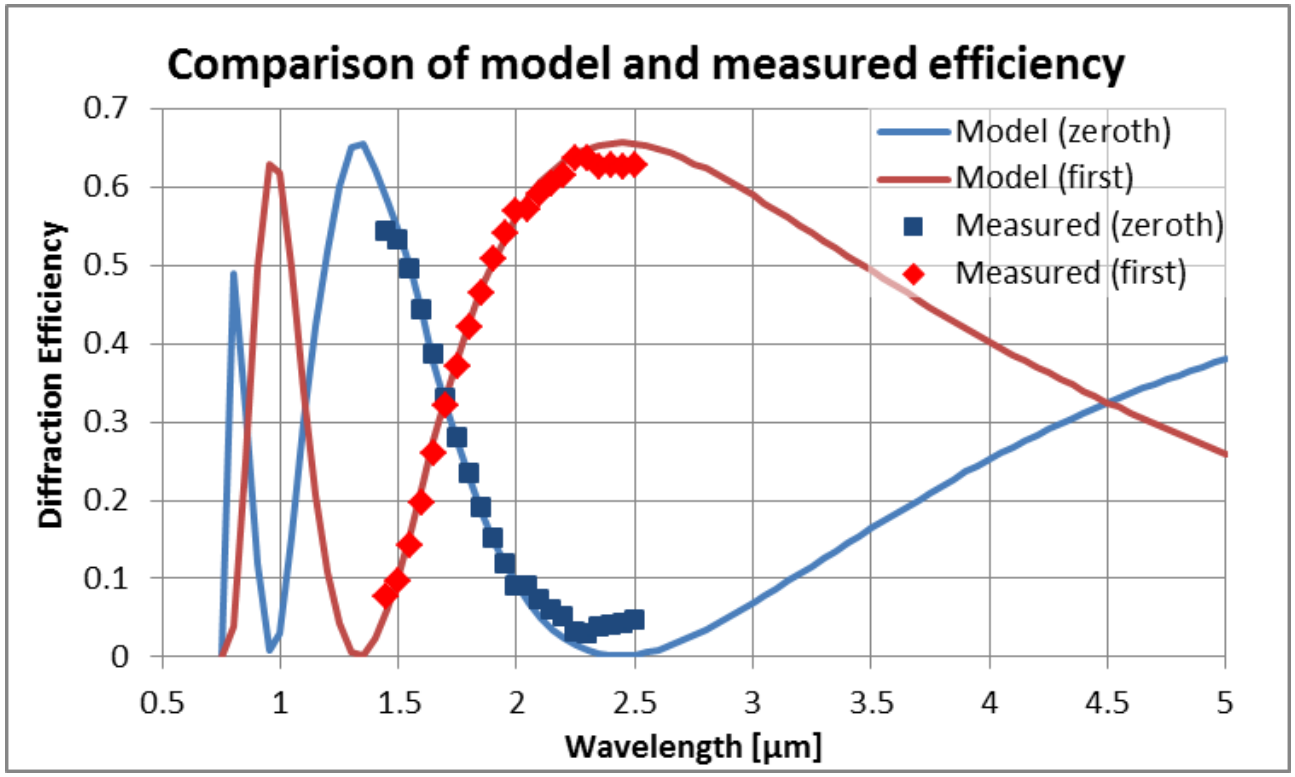
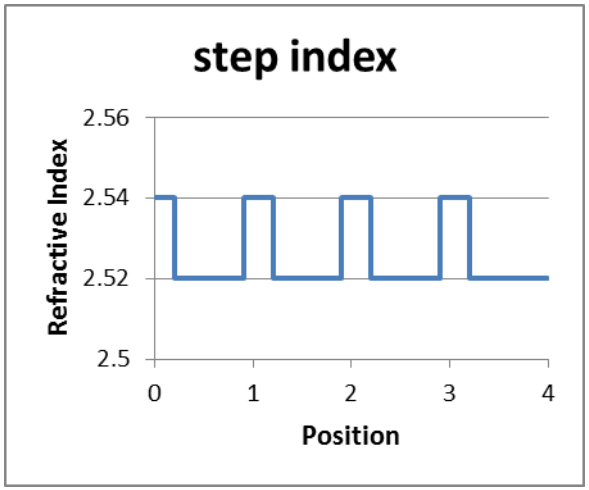
Infrared Efficiency in Littrow





Theoretical grating model uses binary index modulation, $\Delta n \sim 0.02\text{-}0.03$

Glass transmittance is 67% (un-coated)

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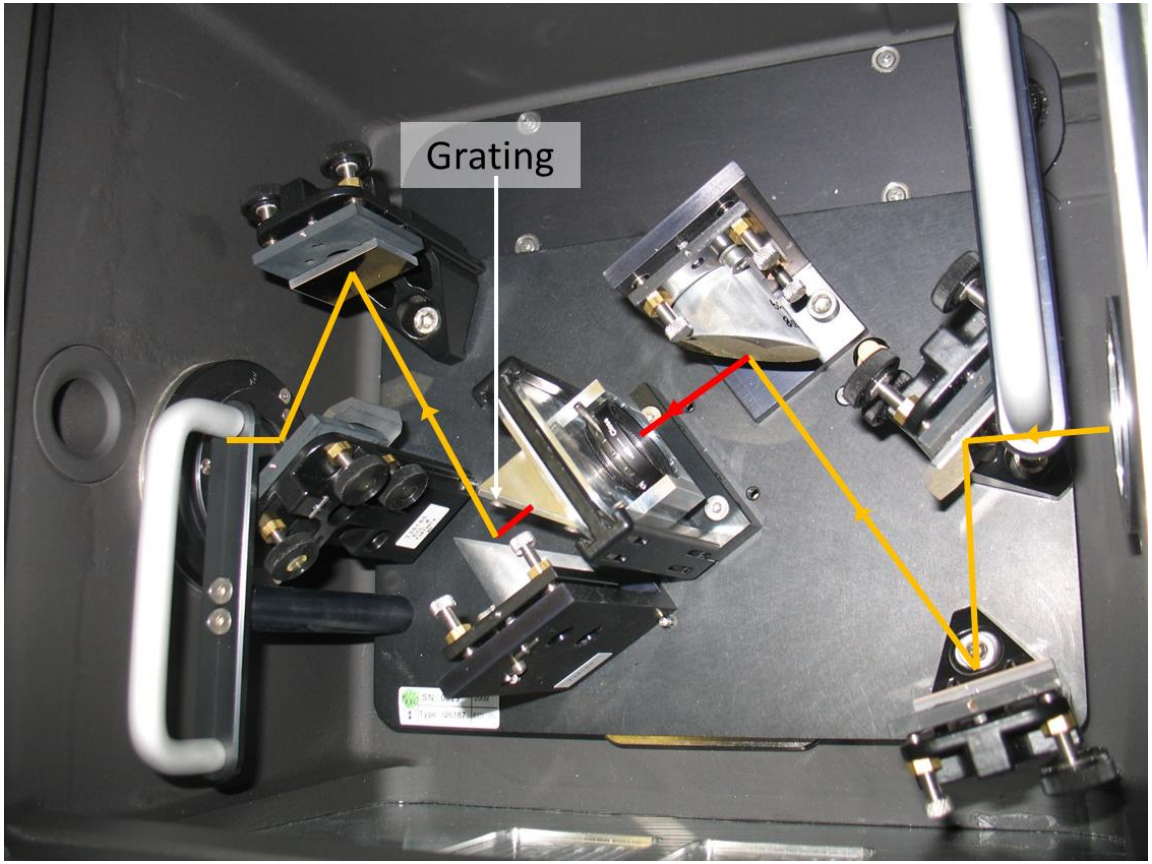
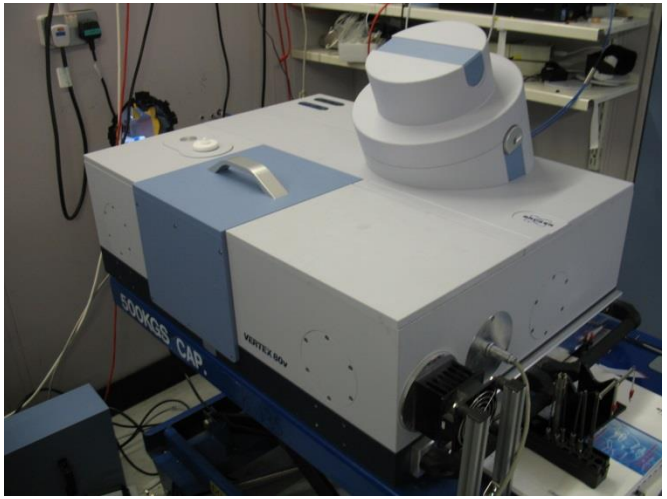
Mid-Infrared FTS Measurements





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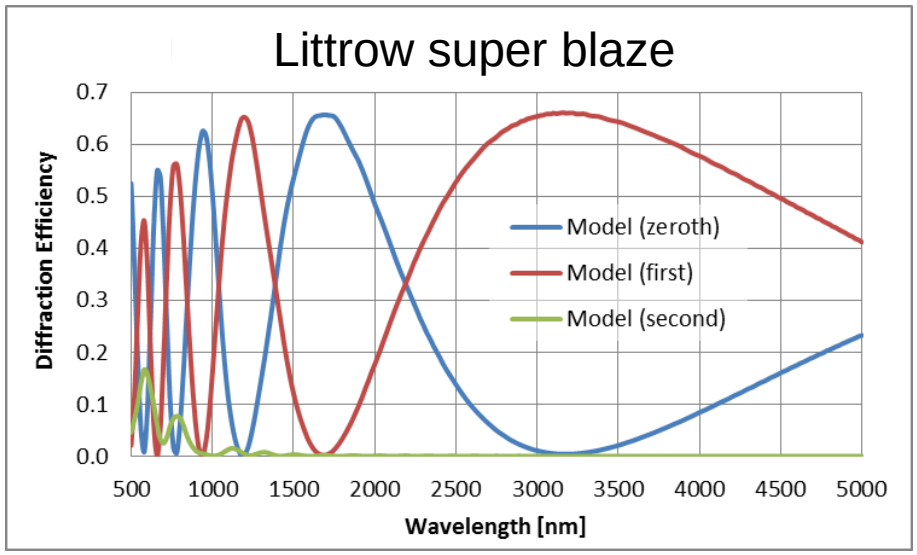
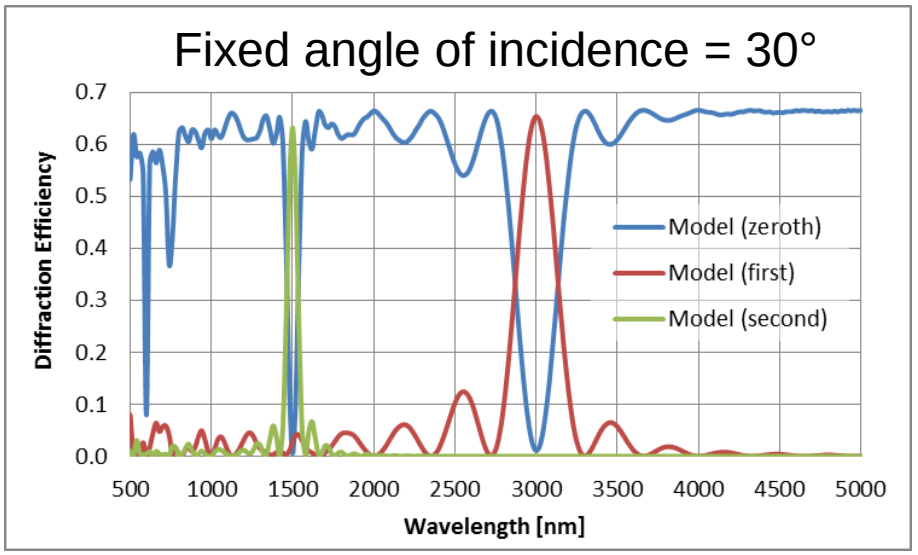
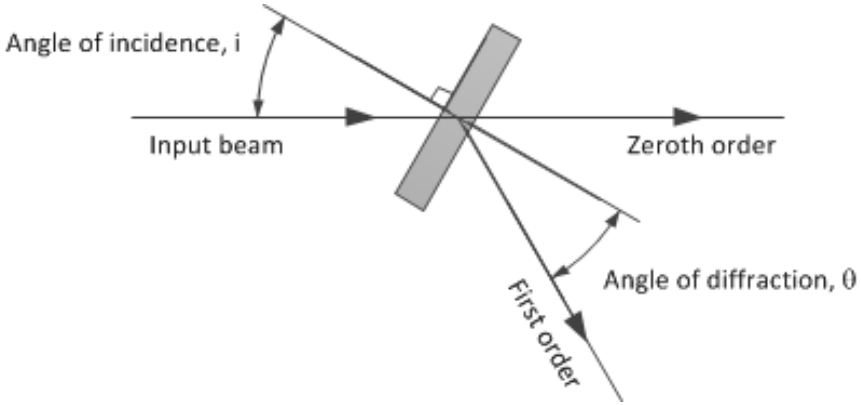
Theoretical Mid-Infrared Efficiency







Theory indicates high second order efficiency (depends on line width).

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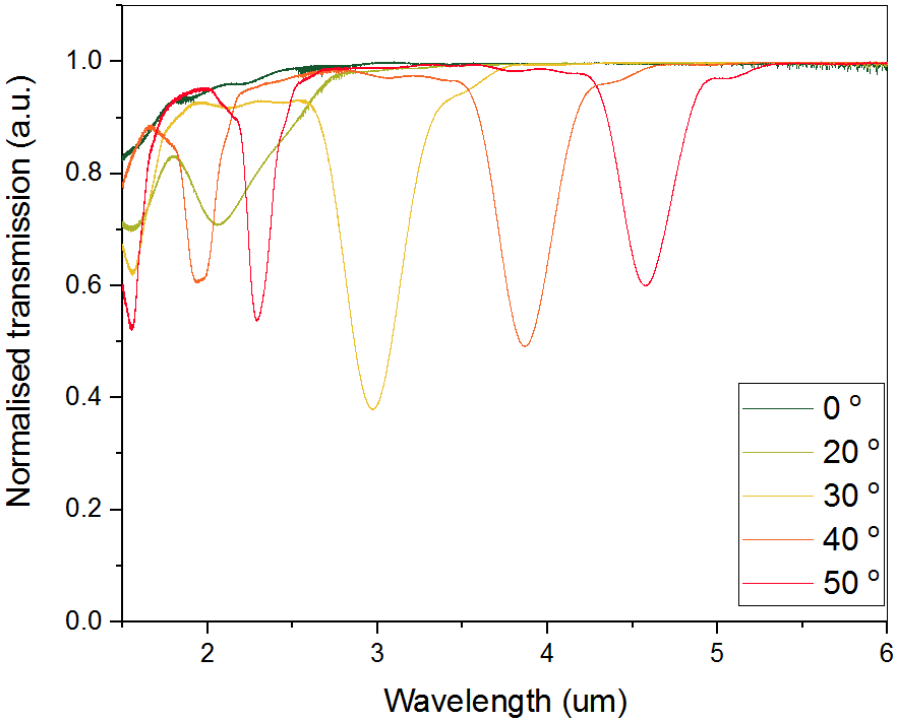
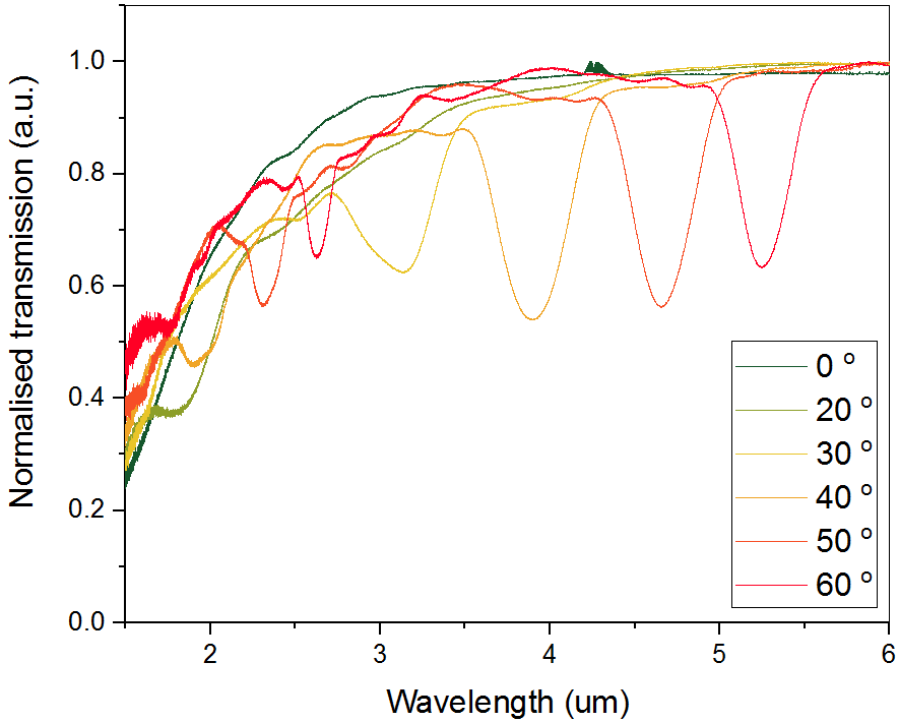
Mid-Infrared Efficiency Results





First order diffraction efficiency is ~50%

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Summary and Conclusions

- Ultrafast Laser Inscription has been successfully used in two materials to manufacture prototype near-infrared and mid-infrared transmission gratings.
- Gratings exhibit high first order efficiency.
- Theoretical modelling indicates minimal efficiency variation with polarisation.
- Tuning the width of the inscribed region changes the high order efficiency.
- Promising results so far but significant development needed to make large astronomical gratings.

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