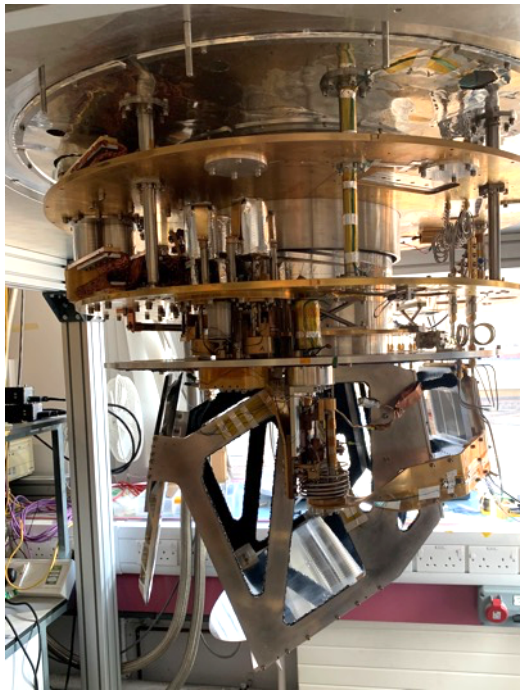
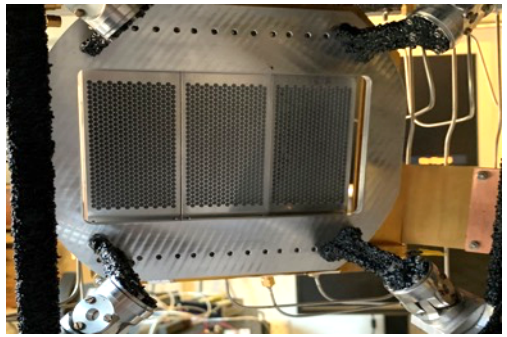
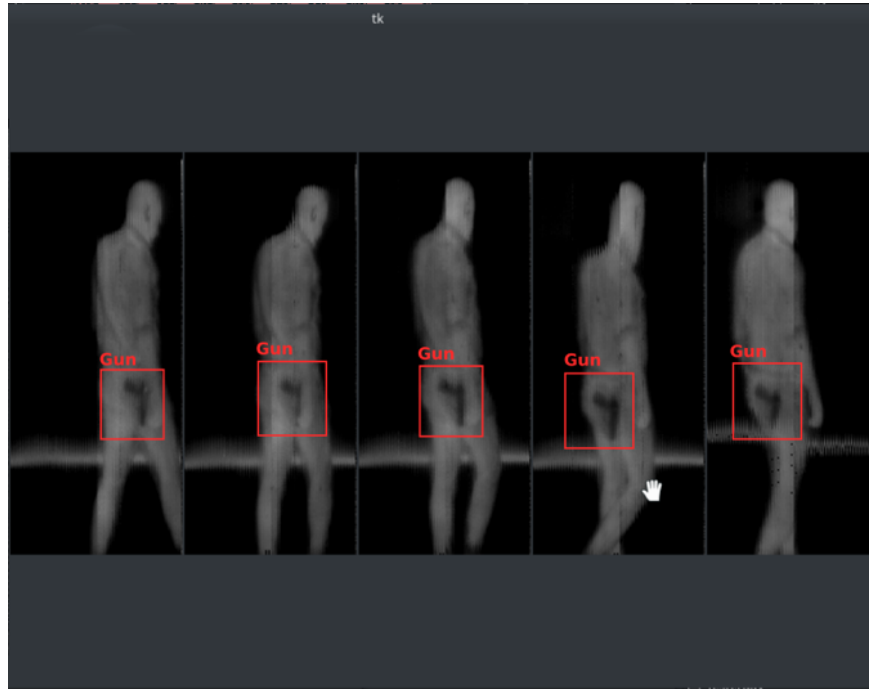
From Astronomy to Security

The Combined output of STFC funded activity and operating Sub-Kelvin Technology in public spaces

Dr Simon Doyle – Cardiff University







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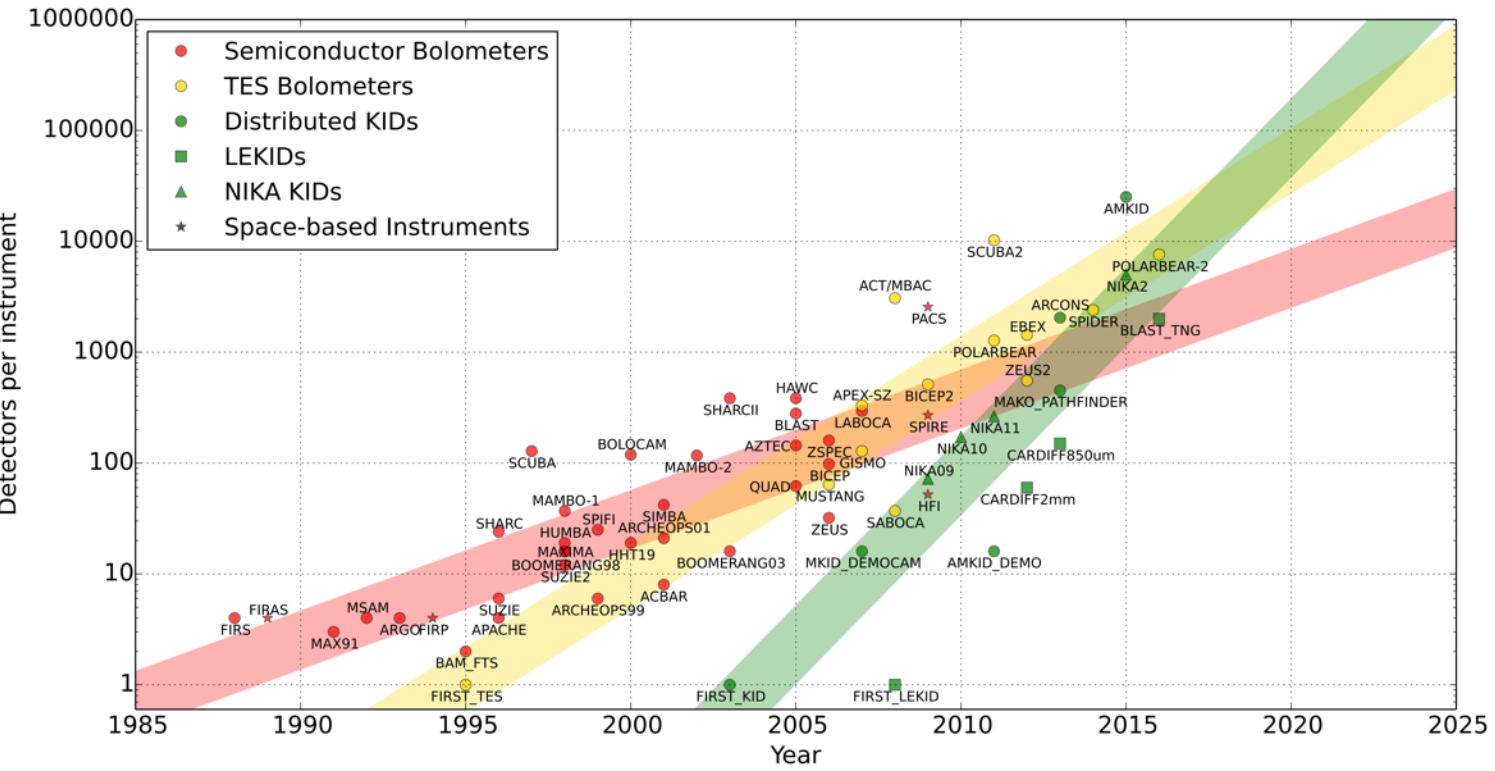
Scope of talk

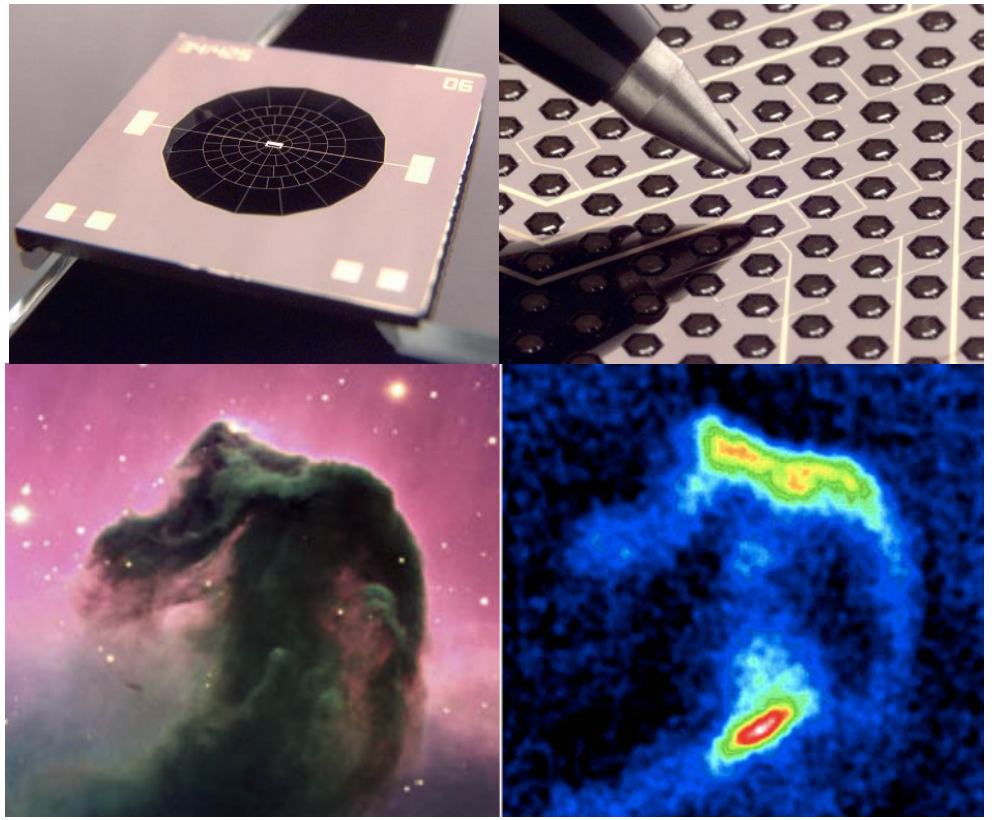
In October 2019, Cardiff University in partnership with QMCi lmt formed a new company specializing in the next generation of walk-through mm-wave security scanners. In this talk we will:

- Introduce the underlying technology.
- Explain the importance of funding from schemes such as IPS and IAA.
- Discuss the lessons learned in realizing commercial exploitation of this technology and the formation of a spinout company.
- Discuss the next steps planned for Sequestim and our development.

Motivation for detector development - Astronomy

- **Semi-conductor technology** Limited to wavelengths of order 200um (1.5 THz)
- **Heterodyne receivers** are typically noisy and not practical for large format imaging arrays
- **Bolometers** have sensitivity but poor multiplexing ratios





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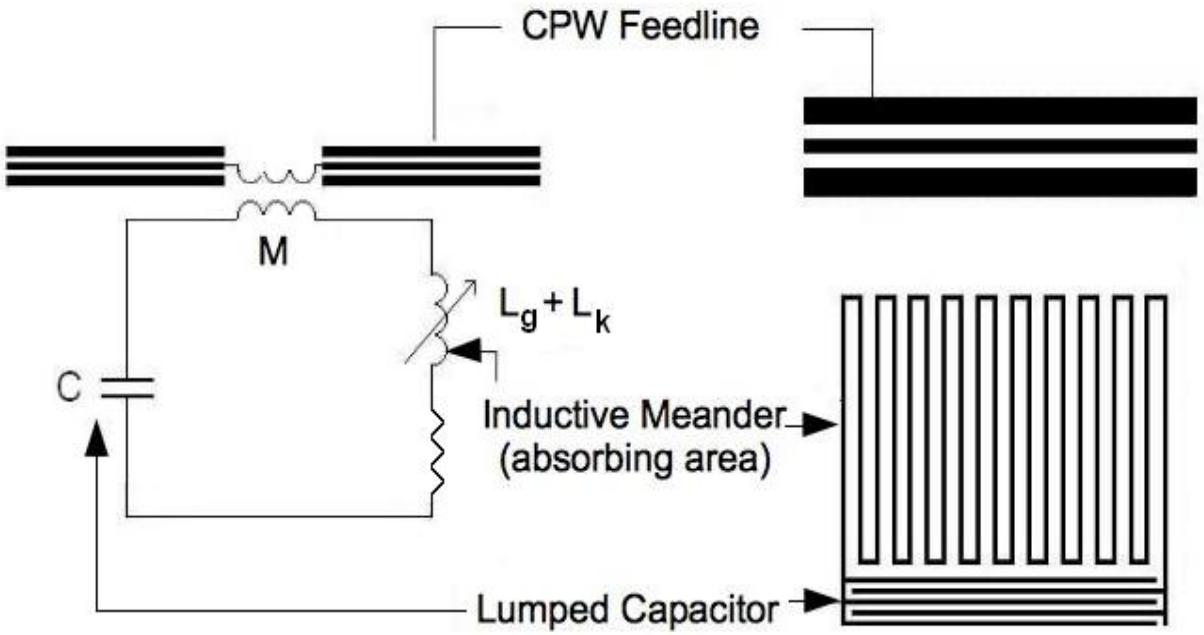
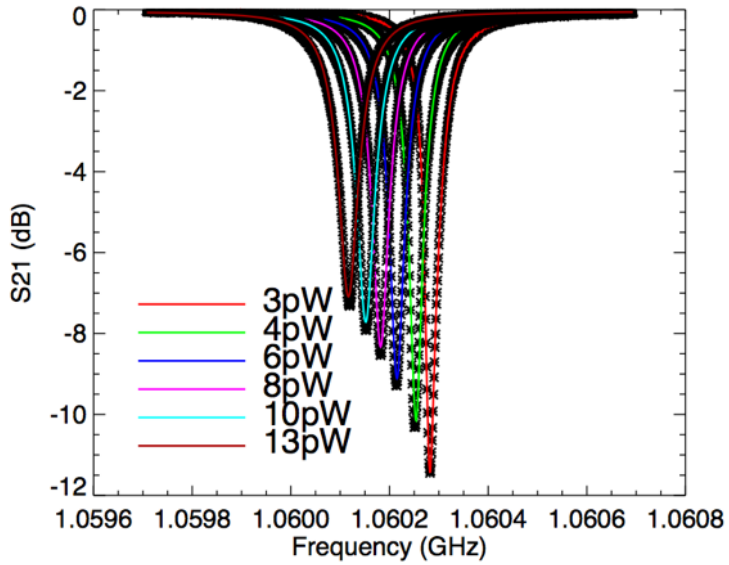
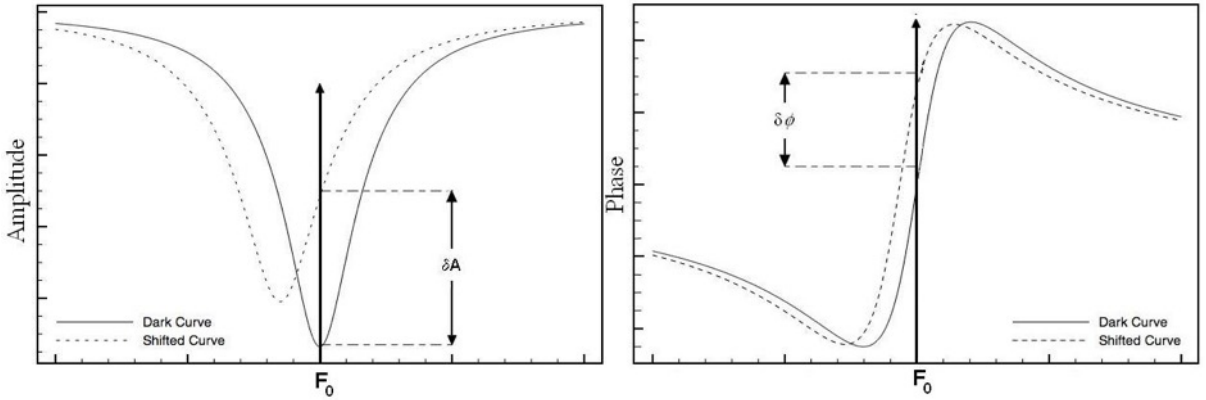
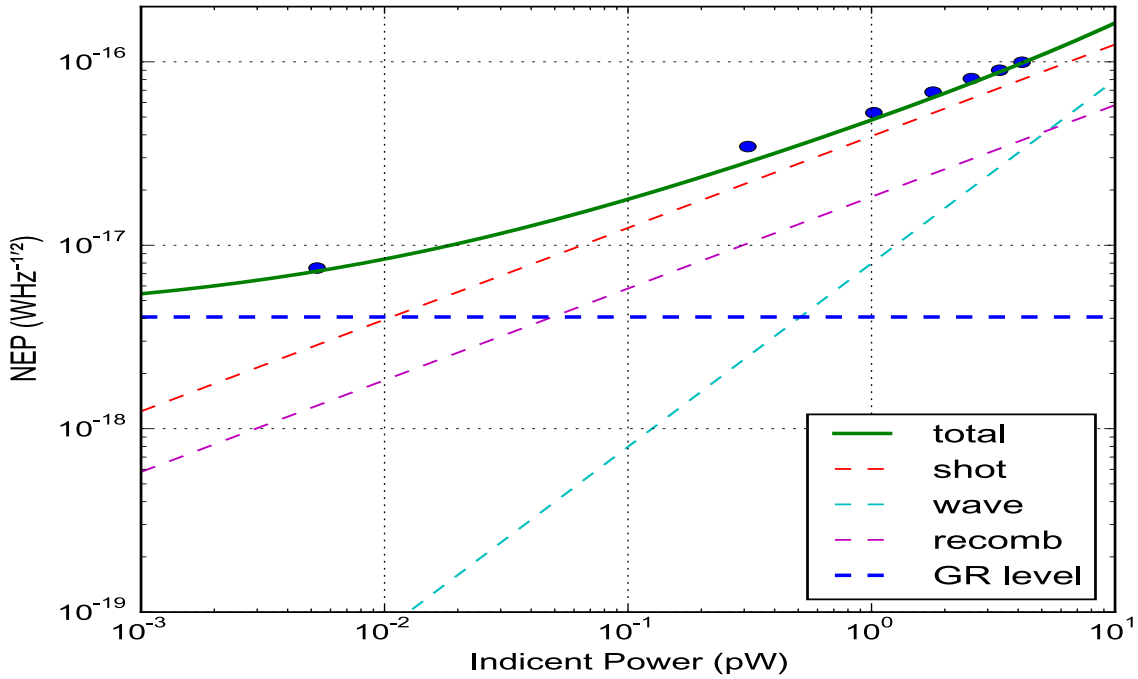
STFC funded technology for astronomy – Kinetic Inductance Detectors









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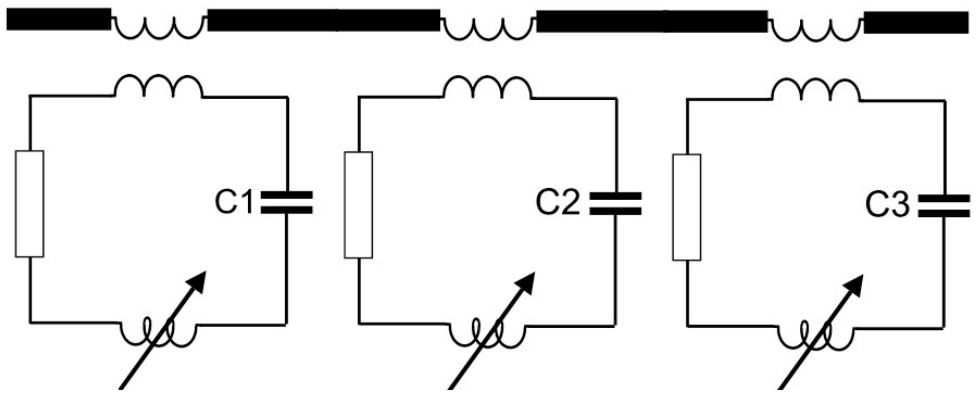
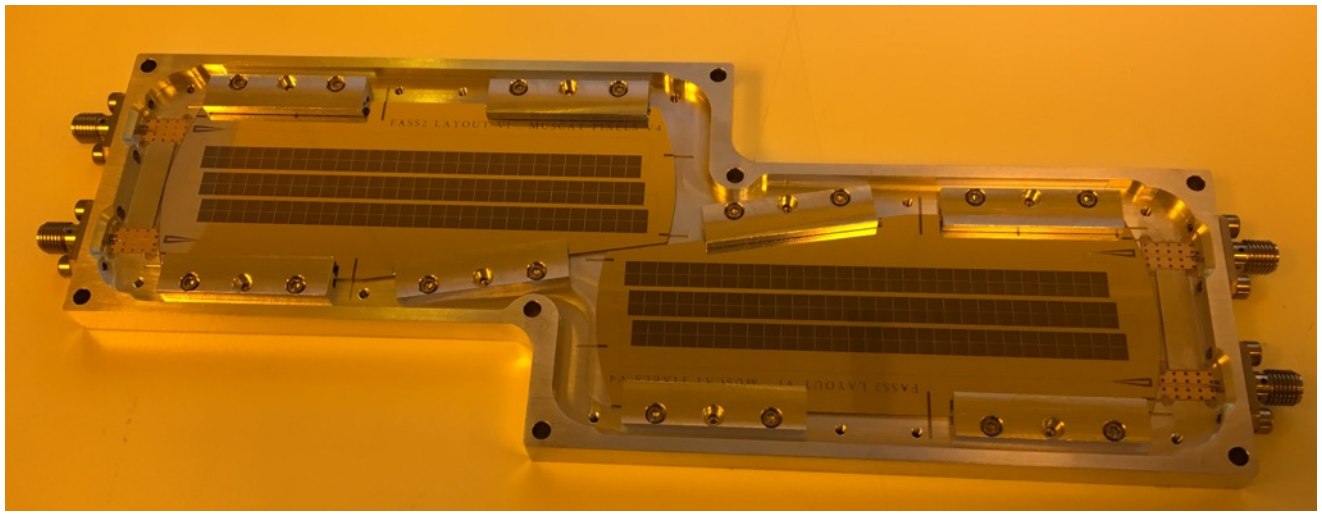
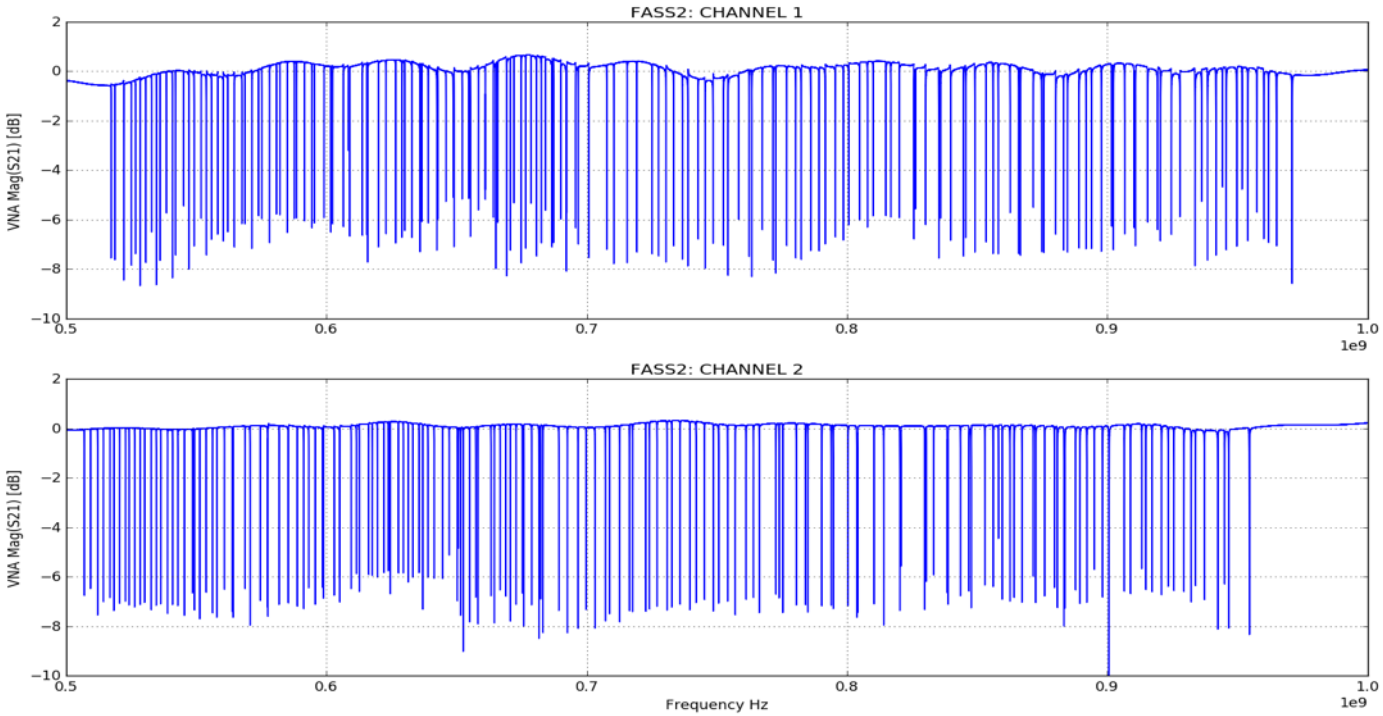
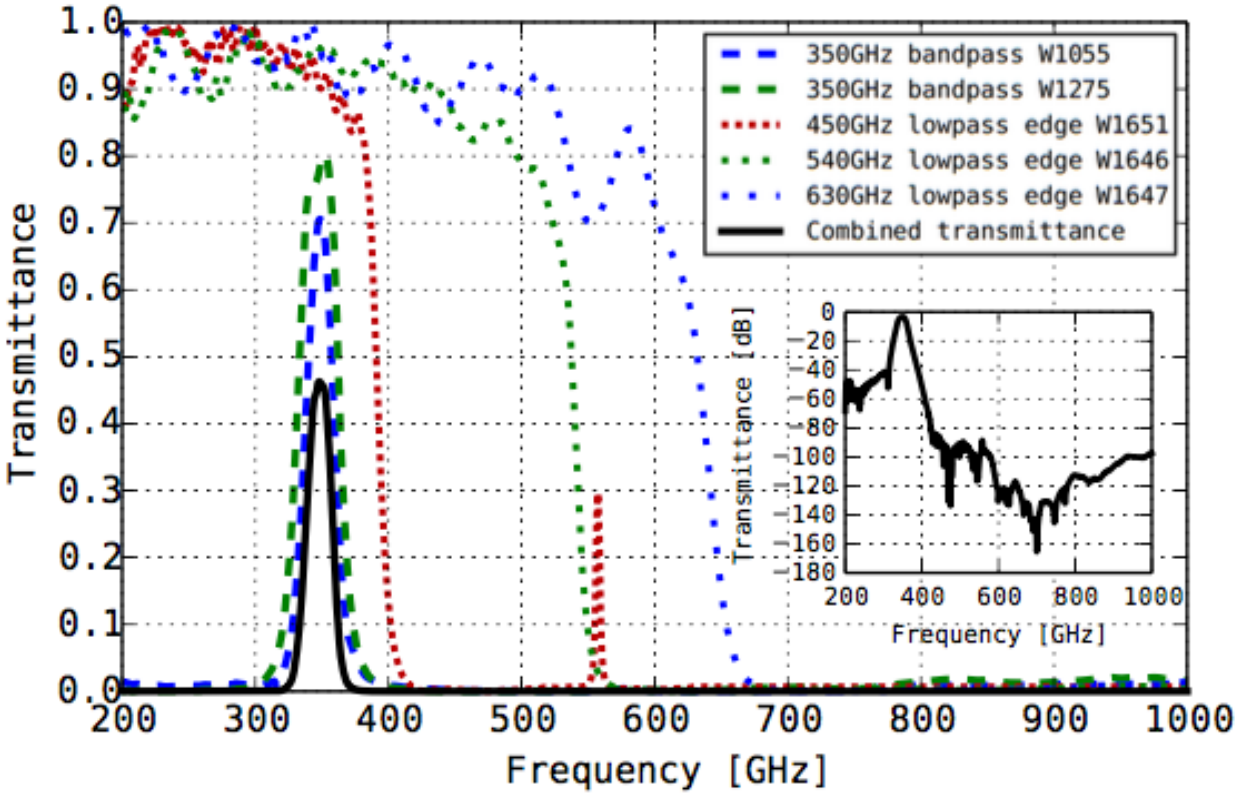


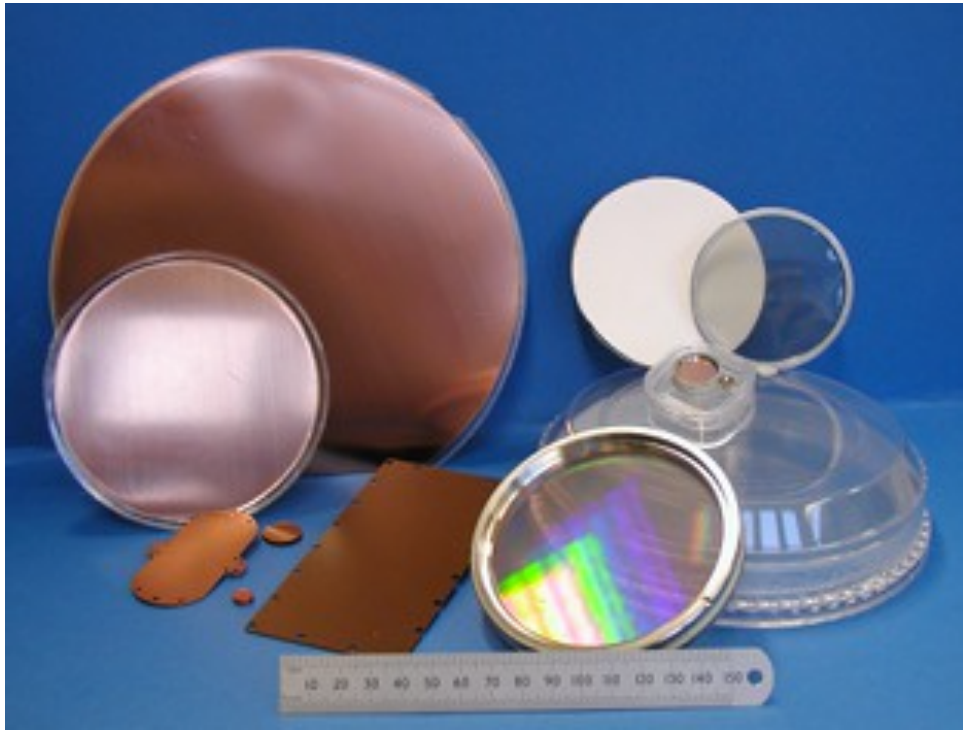




STFC funded technology for astronomy – Filters & Meta-Material

- A technology unique to Cardiff's Astronomy Instrumentation Group
- Enables exquisite out-of-band radiation rejection
- Crucial to achieving the sensitivity required for passive imaging.





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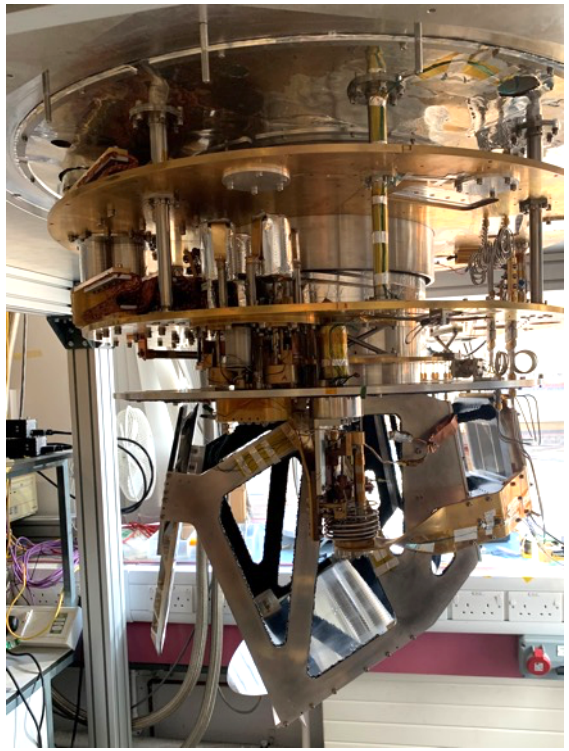
STFC funded technology for astronomy – Filters & Meta-Material

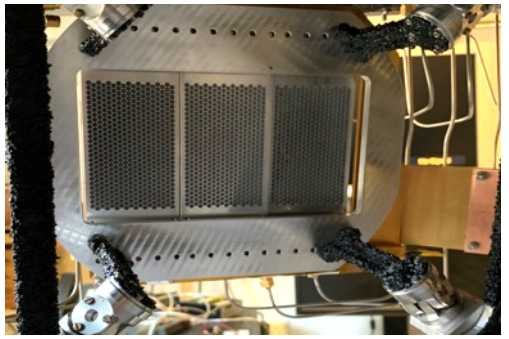
Band selection – How much out-of-band power do we need to reject?

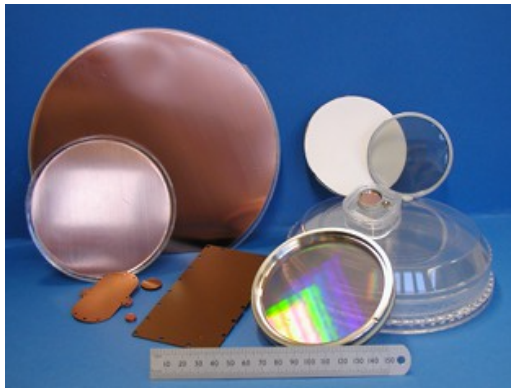
- **Considering thermal power only:**
- Total power through a window 35cm in diameter. $P = \sigma T^4 A \approx 44W$
- In band power on a horn couple detector in a typical 50GHz bandwidth

$$P = 2K_B T \Delta\upsilon = 40pW$$

- 1800 detectors $\frac{P_{tot}}{P_{in\ band}} = \frac{44W}{1800 \times 40pW} \approx 6 \times 10^8$







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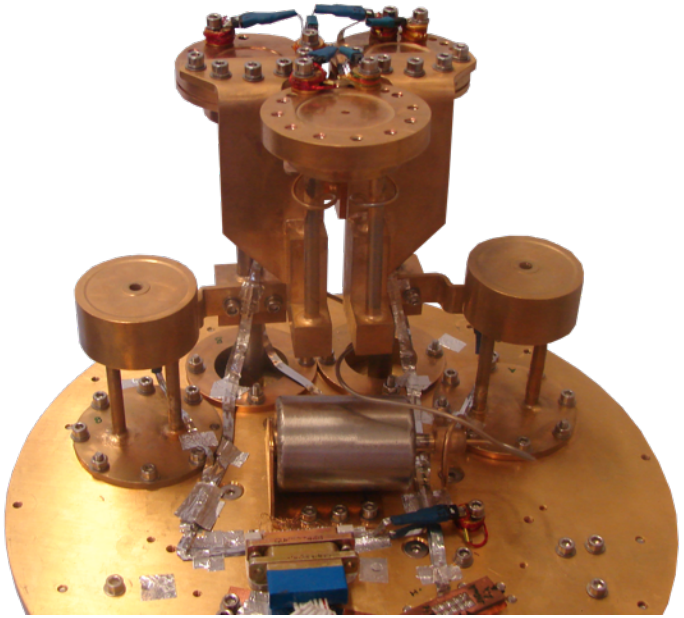
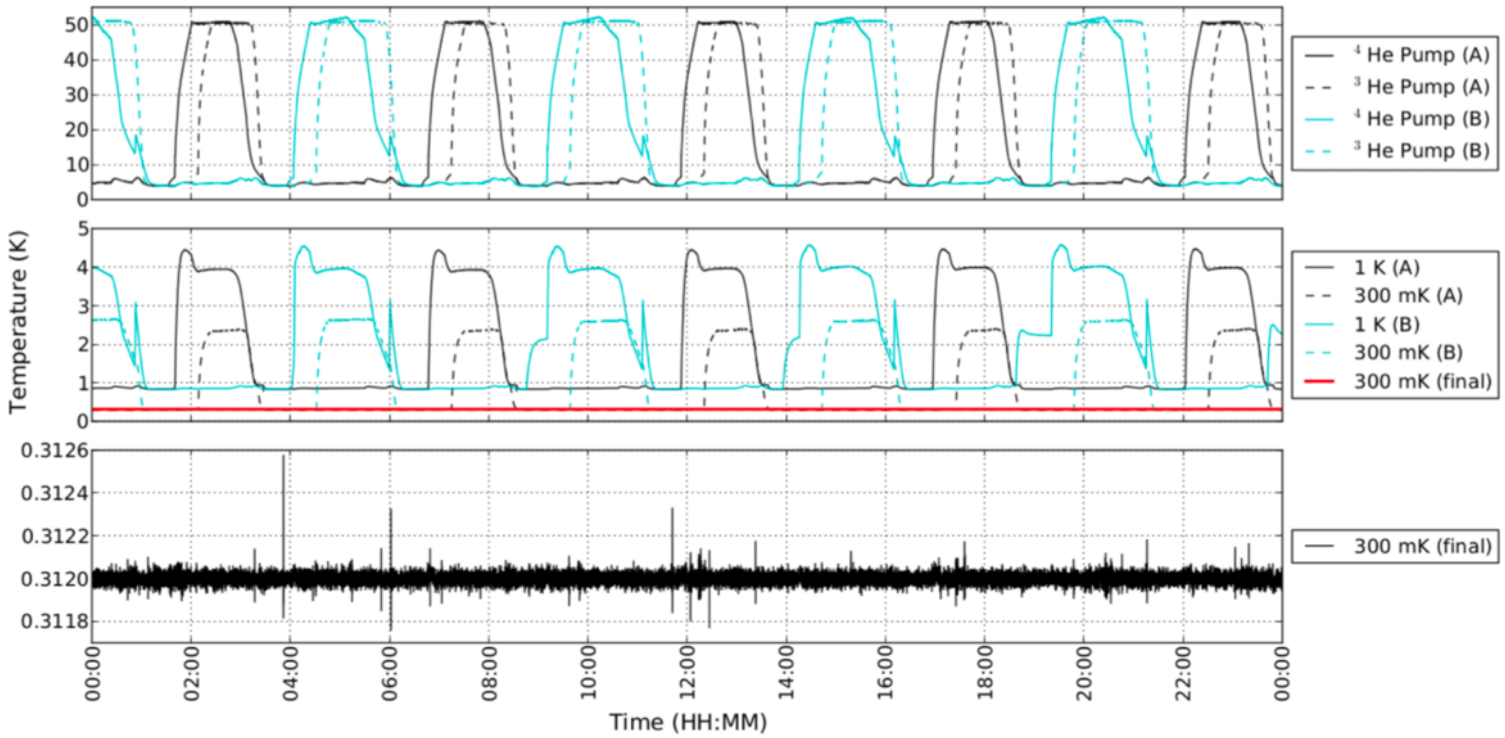
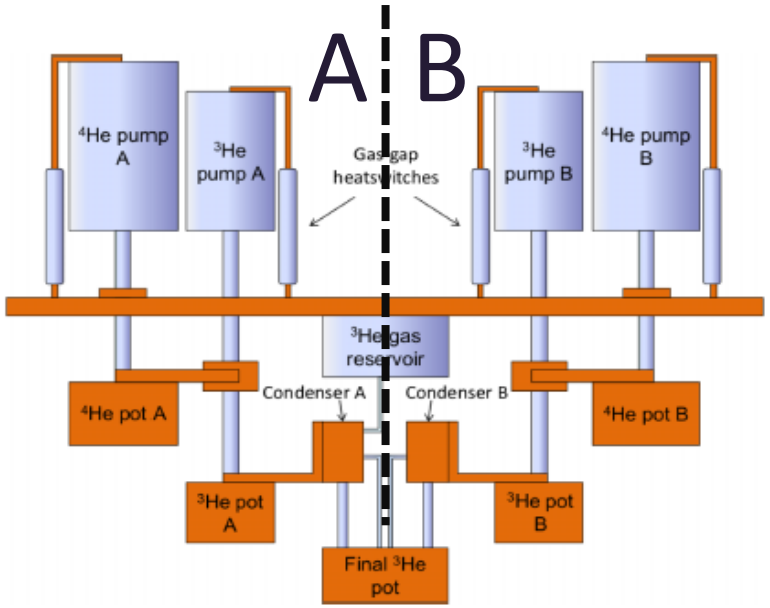
STFC funded technology for astronomy – Sub-K Cooler Technology

- Continuous version of a sorption cooler developed with Chase Cryogenics through an IPS program. Temperature range ≈ 250 – 350 mK
- Continuous and single shot versions developed through on-going work with Chase Cryogenics. Temperature range ≈ 220 – 250 mK
- Closed cycle dilution units also developed. Temperature range ≈ 90 – 150 mK







Formation of Sequestim

- 2010 - Idea floated of using KID based detectors for industrial applications.
- 2011/12 Seed corn funding provided by QMCi. STFC funded PhD student working full time.
- **2015** – IPS funding awarded to develop a generic camera for commercial applications providing:
  - Dedicated PDRA and Academic effort
  - Crucial hardware
  - Official project status
- **2016** – IAA funding provided optics to tailor our generic system for truck scanning.
  - Proved principle but stalled due to government spending review.
- 2016 – Formation of Sequestim
- **2017** – IAA funding provide funding to tailor our generic system for air passenger screening
- 2017/18 – Funding provided from governments Future Aviation Security Sector (FASS).
  - Combined imaging with AI threat recognition
  - Proved technology can work in an airport environment. Demonstrated in Cardiff Airport 2018.
- 2019 – Technology license agreement signed between Cardiff University and Sequestim.

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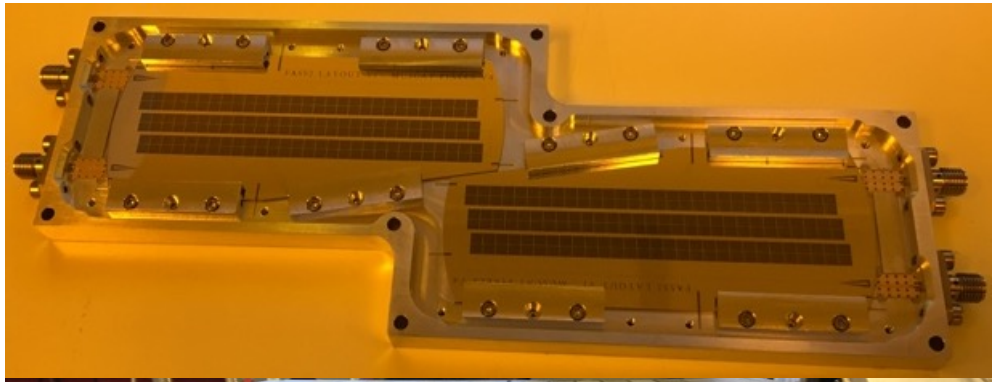
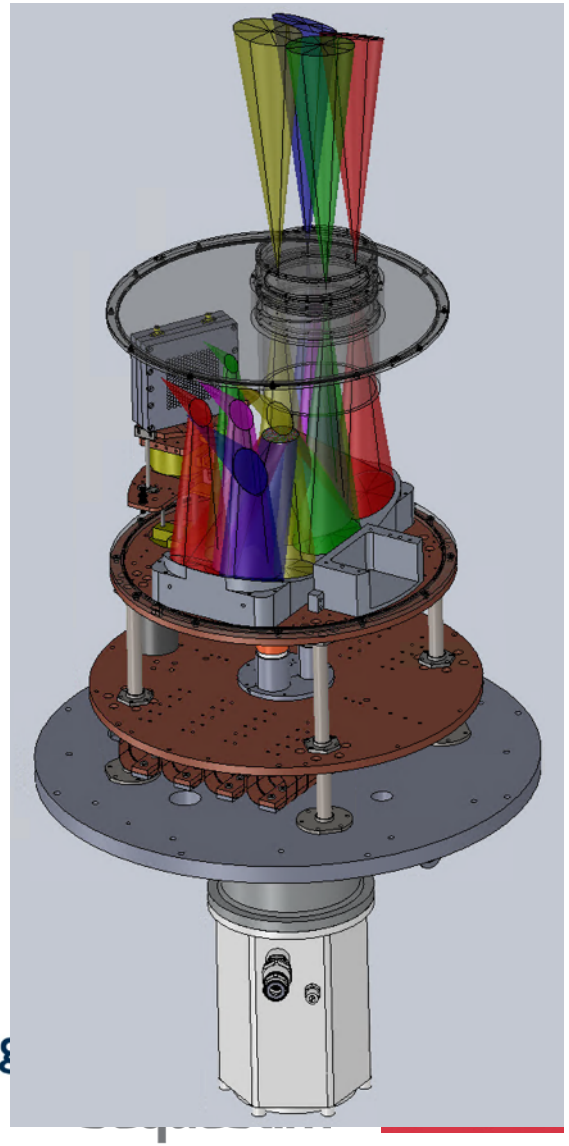
IPS Original objective

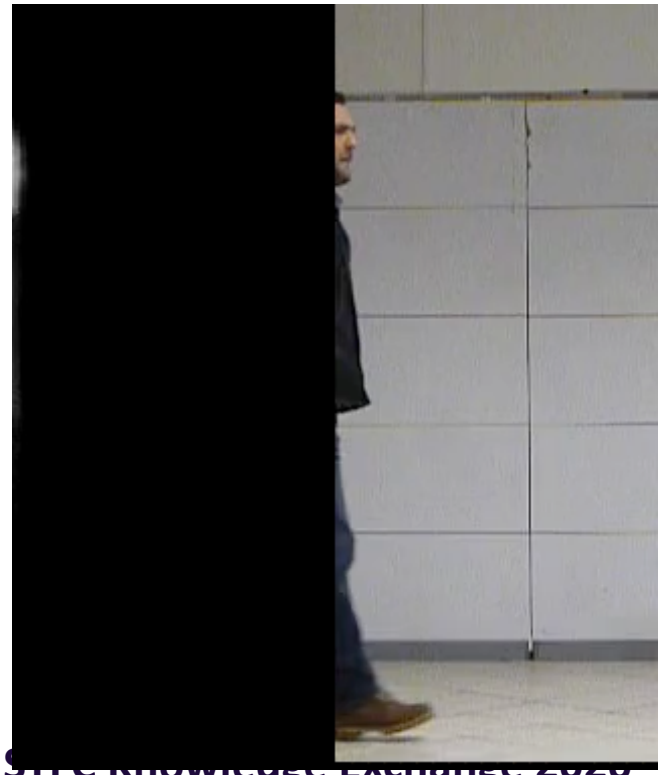
- To develop a generic mm/submm camera based around Lumped Element Kinetic Inductance Detectors.
- Steps to achieve this goal included:
  - Development of a cryogen-free sub-K platform ✓
  - Development of an all reflective optics system based upon an Offner relay ✓
  - Development of a LEKID based imaging array ✓
  - Development of detector readout ✓

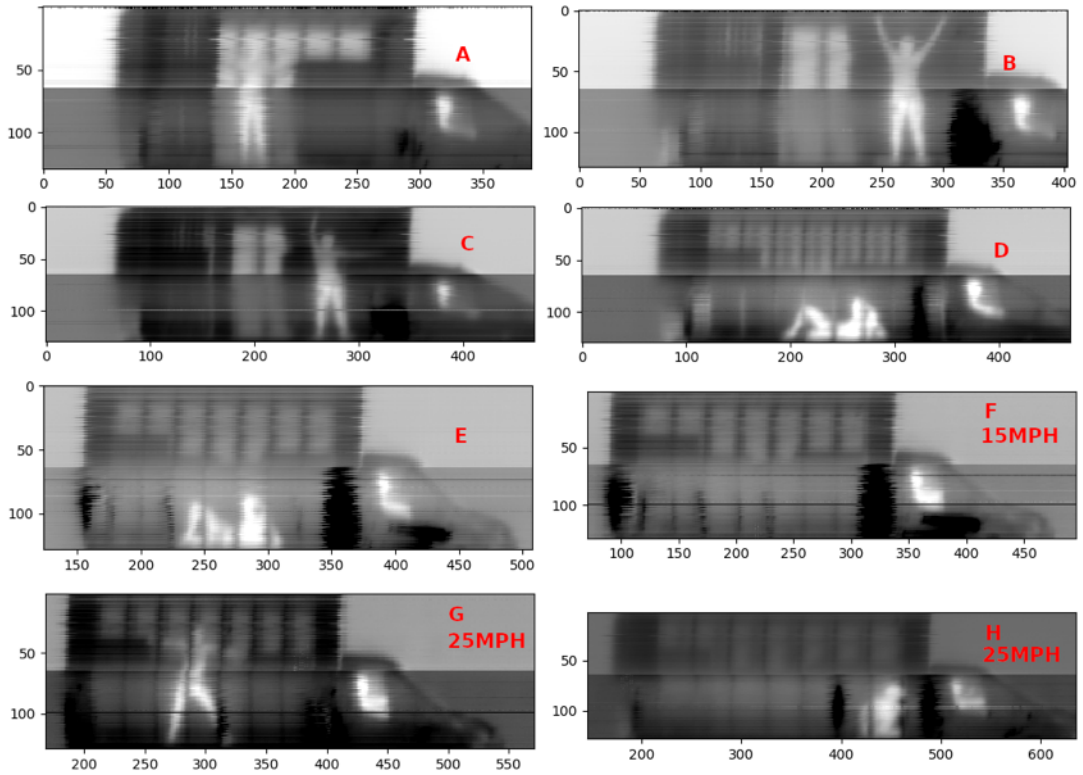




IPS Extension - Focus on security applications

- A proof of concept camera was deployed at Cardiff Airport in December 2018.
- The system was adapted for freight screening in the summer of 2019.
- This work has been very successful and has generated many interested parties including: British Airways, UK border force, The Welsh Development Bank and several private investors
- Has attracted a lot of media attention including a 6 minute item on the national 22:00 news



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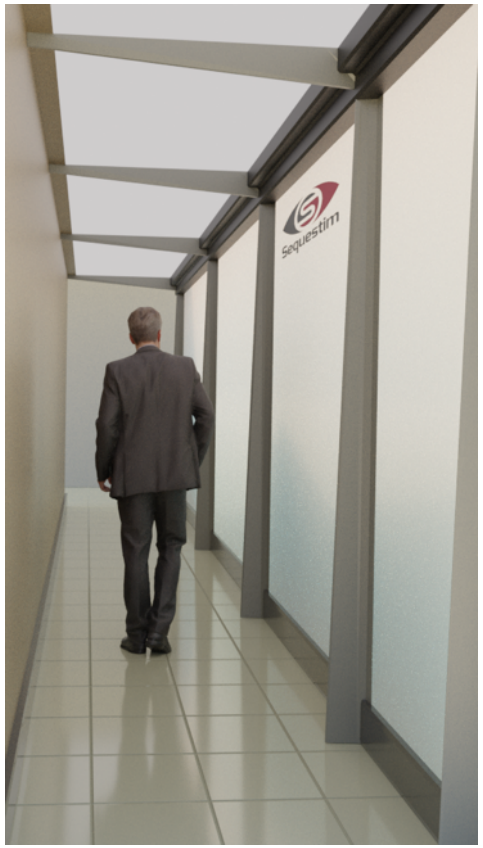
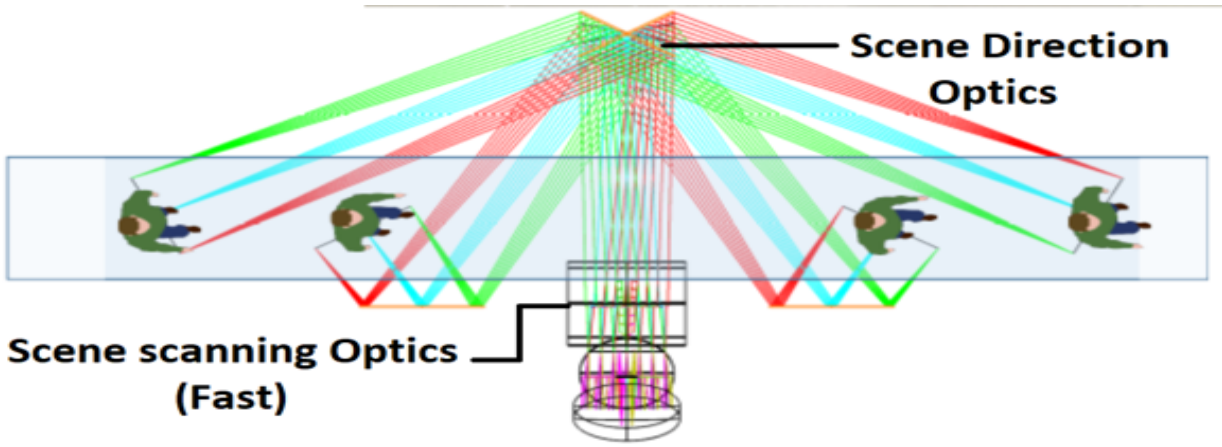
Moving forward

- Investment and research funding required to develop a system optimized for air passenger security screening:
  - Will develop continuous cooling system
  - Will develop new scanning optics
  - Will develop new readout electronics
  - Dual colour detector arrays



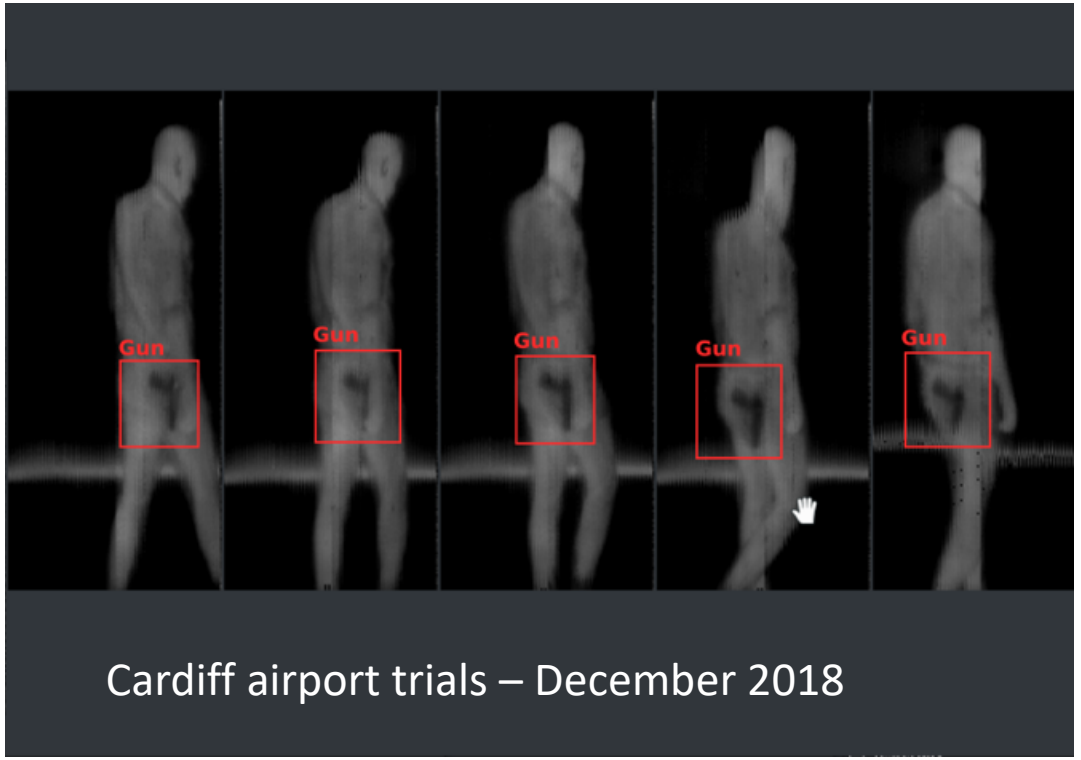
- **Ultimate aim - to have a robust system that can be certified and deployed in air-passenger screening (ECAC and TSA)**

Expect a call to tender for vehicle screening from UK Border Force in early 2020.



Moving forward – AI development

- Cardiff demonstration was successful, but AI training was cumbersome (manual markup of 10,000 images)
- Demonstration in Gatwick Airport – February 2020
- Field testing to prove continuous cooling.
- New scan system
- AI ”white list” training
  - Train system to recognize what is safe
  - Flag anything unrecognized



Cardiff airport trials – December 2018

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Lessons learned in forming a startup company

- Proactive commercial partner is crucial to provide:
  - Market knowledge.
  - Market access.
  - Understanding of investor requirements.
- Identify IP and unique capabilities as early as possible.
- Focus on single aim.
- Extrapolation of results does not carry much weight in the commercial world.
- Comprehensive funding is crucial:
  - Attracting investor funding for blue skies activity and proof of concept is difficult to achieve.
  - Working prototypes clearly demonstrate potential.

Conclusion

- We have developed a technology with the potential to revolutionize air passenger and freight screening using mm-wave technology.
- The novel use of sub-K detectors operating in cryogen free systems would not have been possible without IPS funding.
- IAA funding was crucial in assisting the demonstration of this technology for security-based applications.
- Investor funding now being sought to prepare version-1 product for ECAC and TSA certification.
- Research funding being sought to realize full potential of this technology.
- **Industrial applications are now feeding back into research!**

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