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INSTITUT FÜR LASERPHYSIK

Light sources and technology at 2µm

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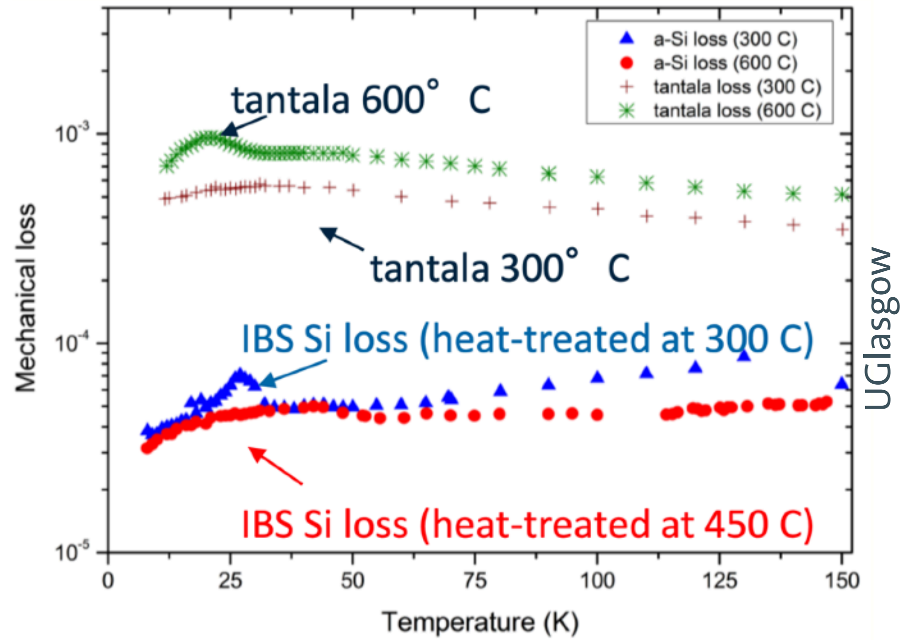
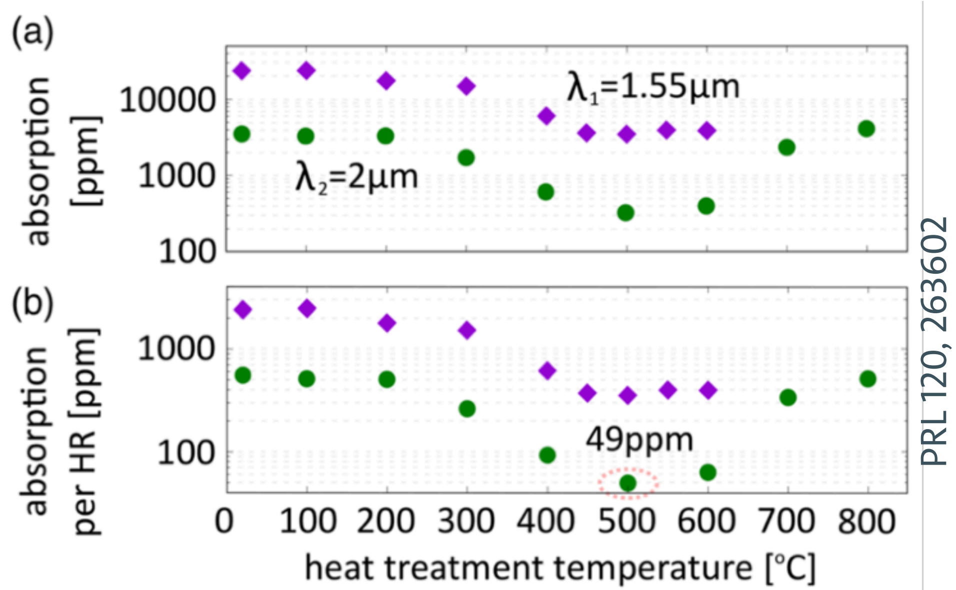
DFG grant #388405737

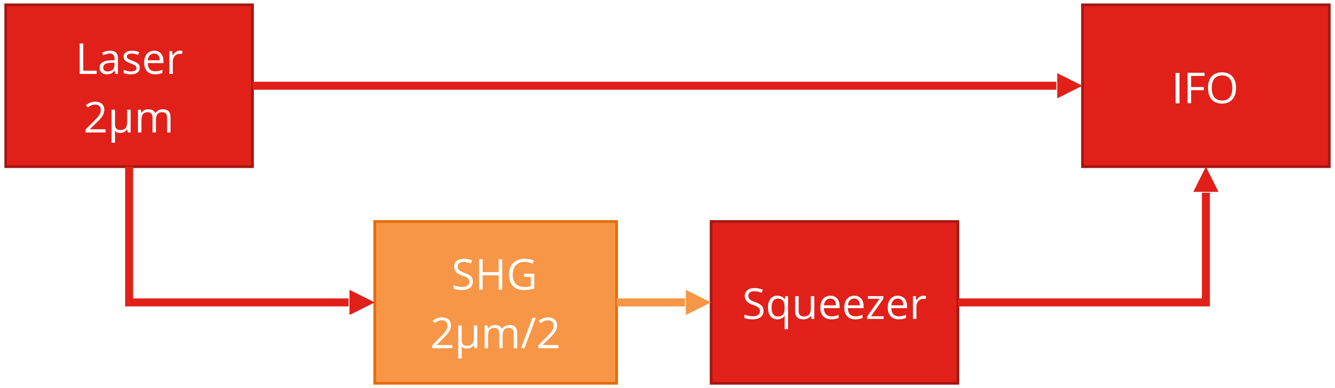
Motivation for 2µm

- fused silica substrates lossy at low temperatures
  - Si interesting option and available in reasonable diameters
  - requires shift to λ ≫ 1.2µm, e.g. 1.55µm
- can Si replace high-loss tantala in coatings as well?
  - much lower loss, much higher refractive index contrast requiring fewer layers
  - but absorption at 1.55µm still high, need to go further towards 2µm





Degenerate OPO for 2.128µm Generation



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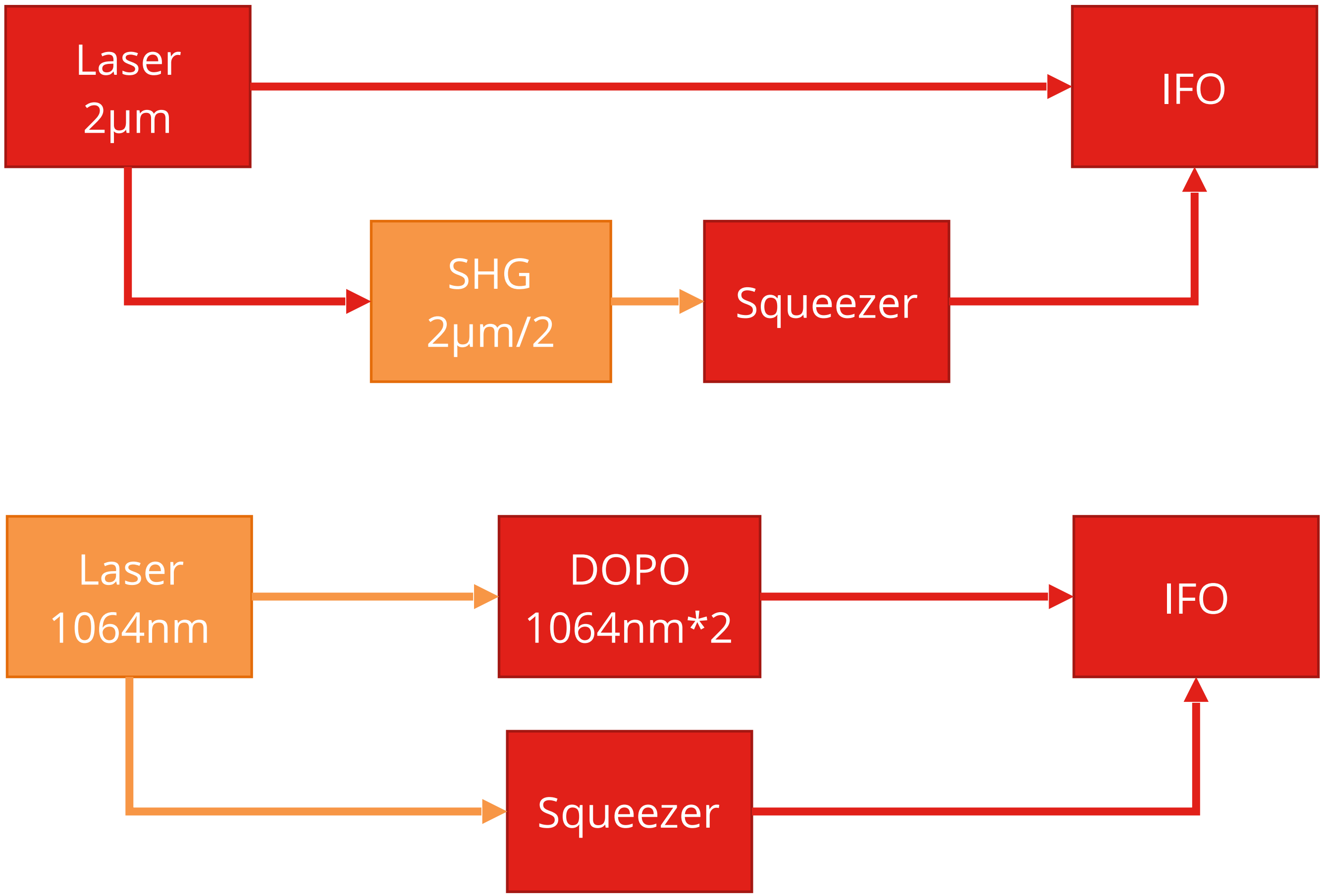

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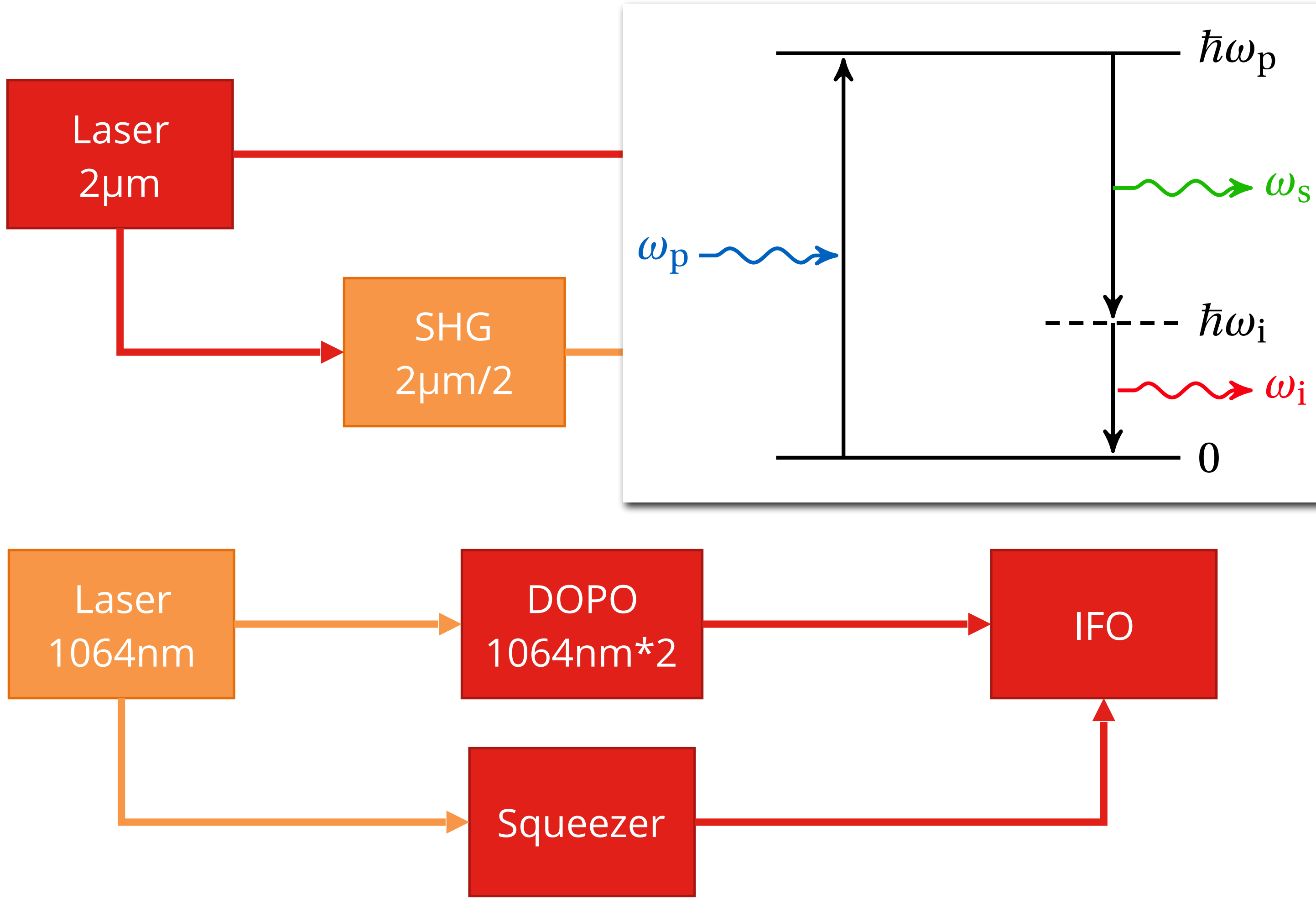
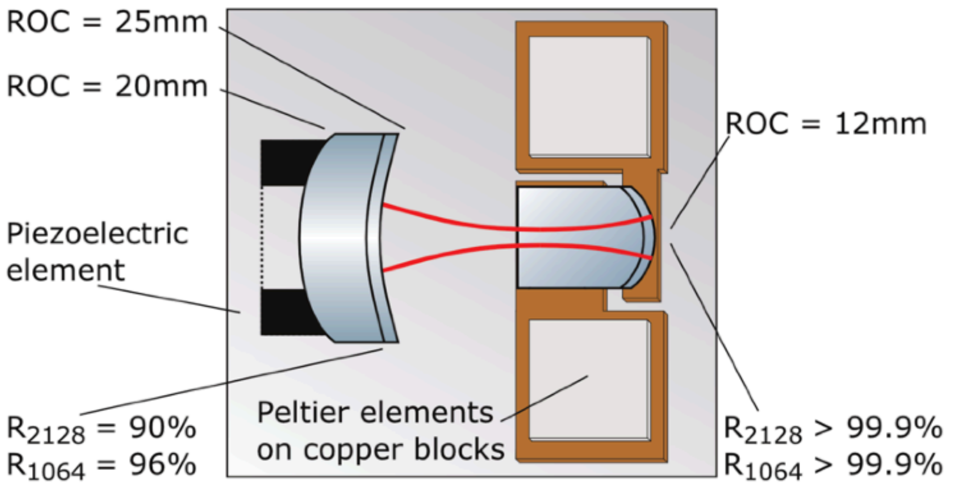
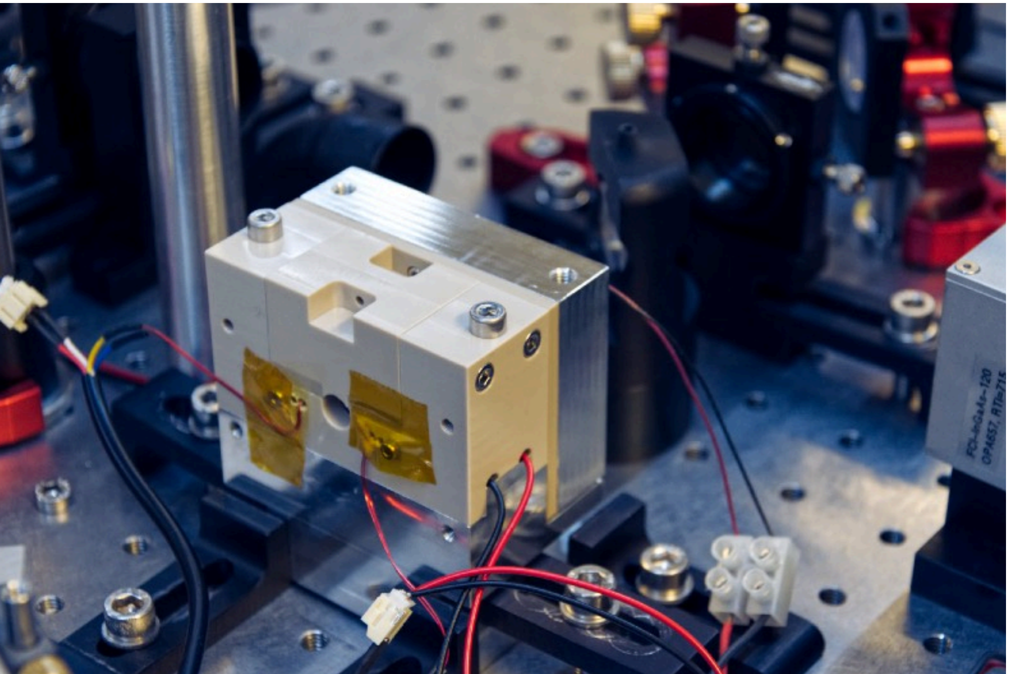


Setup: DOPO and two temperatures

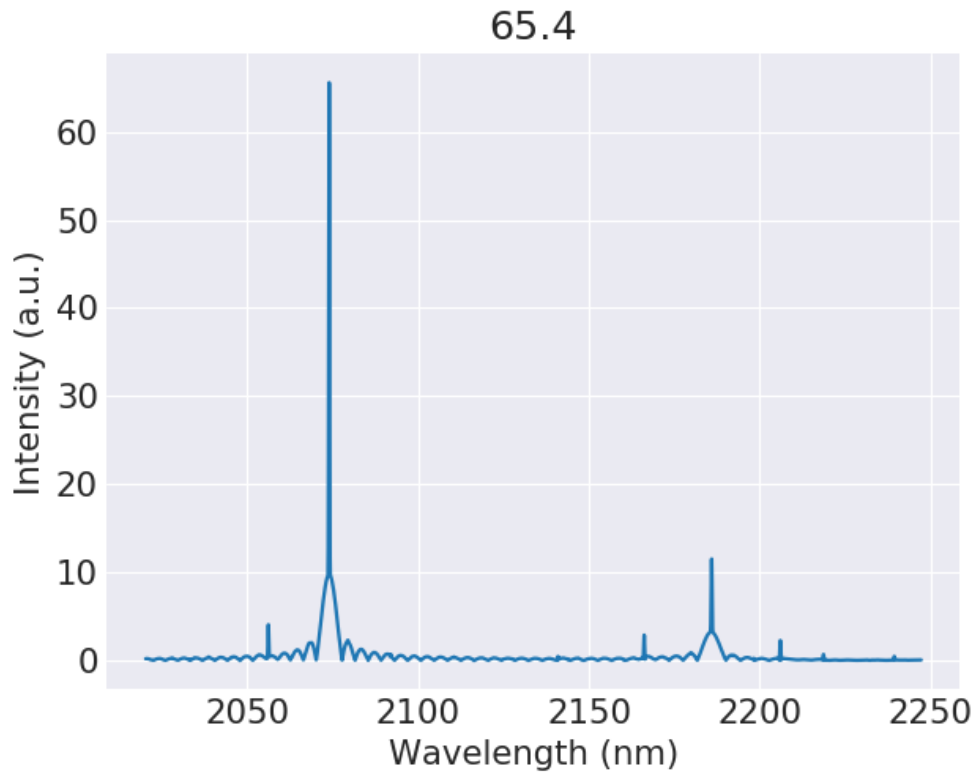




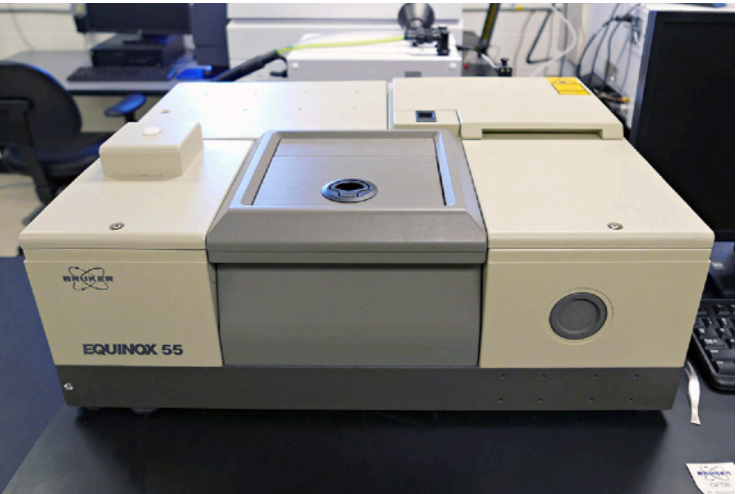
- well-known materials such as periodically-poled KTP work for this process
- doubly-resonant linear cavity, crystal divided into two temperature regions:
  1. bulk of the periodically poled region for optimal phase-matching
  2. some small end bit to compensate round-trip phase difference between pump and signal/idler

First results: OPO Wavelength Tuning

- measured OPO output spectra for different temperatures of the nonlinear crystal
- degeneracy reached at around 70°C (higher than expected, needed some redesign of our OPO to reach those temperatures)



Temperature-dependence of signal/idler output wavelengths



Bruker Equinox 55 FT-IR Spectrometer
(picture from UWLAX, ours looks similar)

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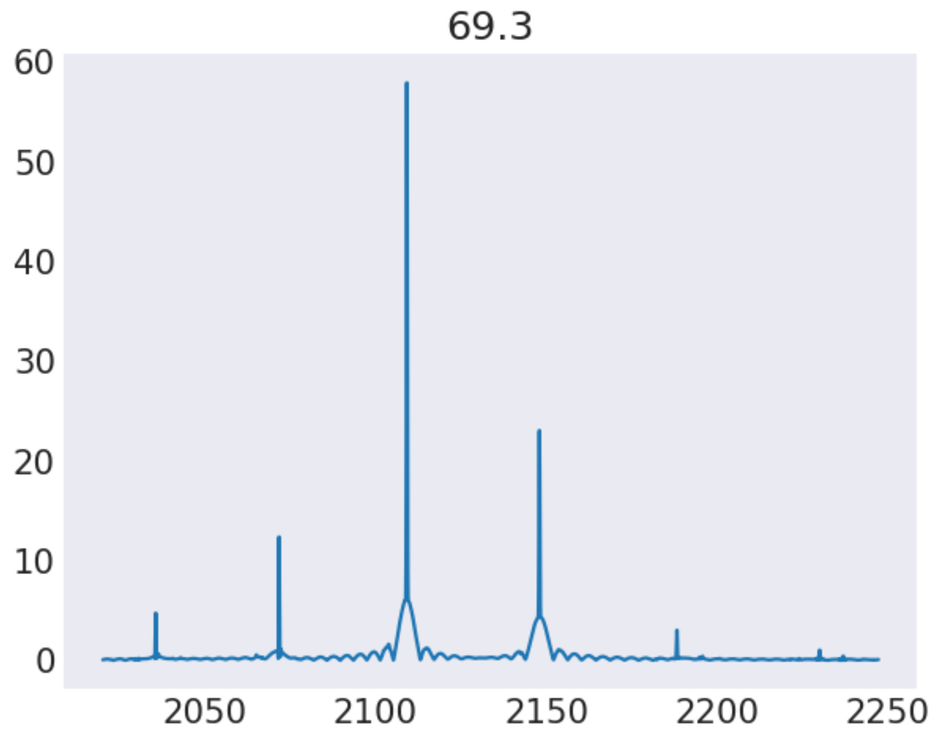

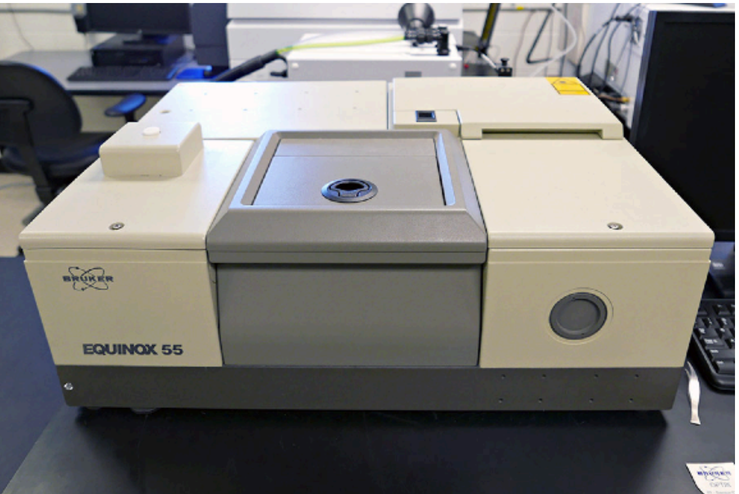

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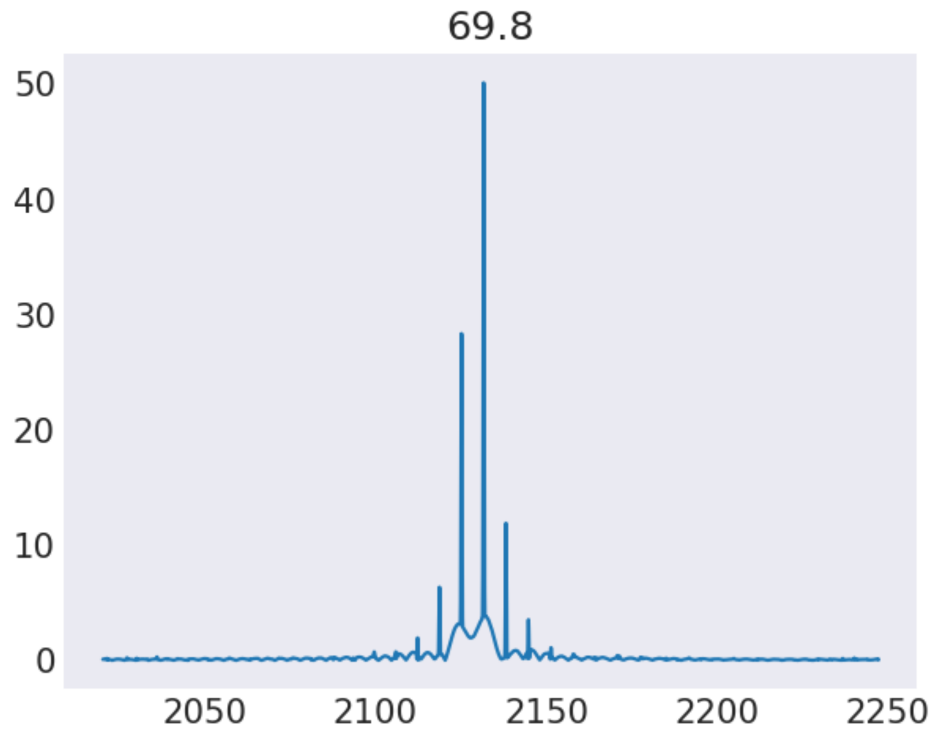

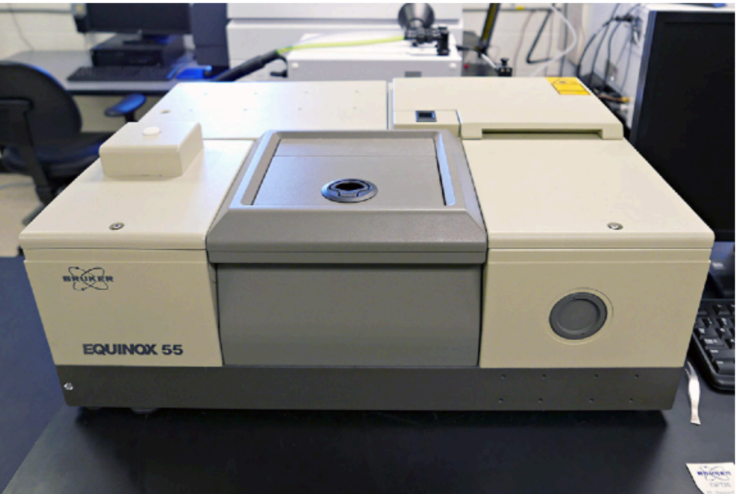

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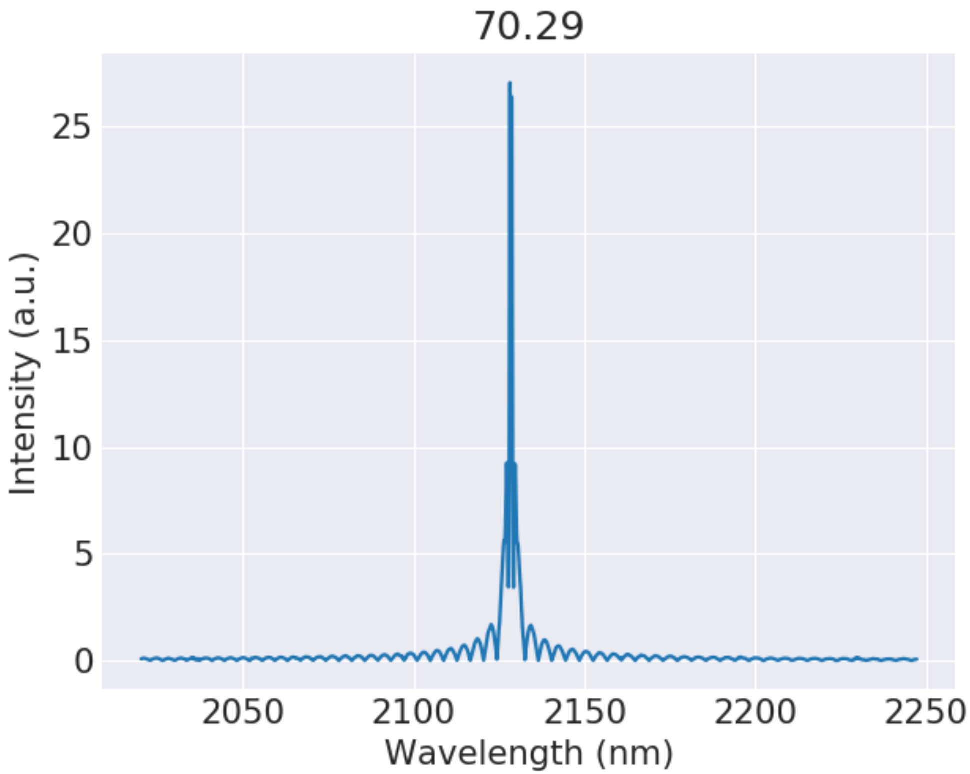

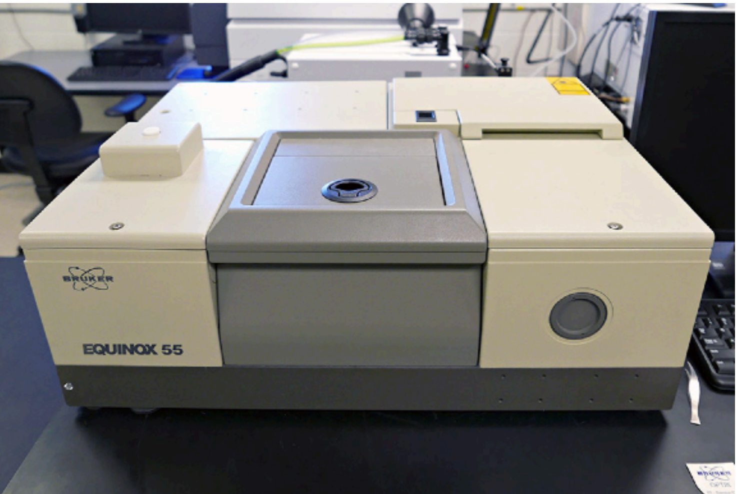

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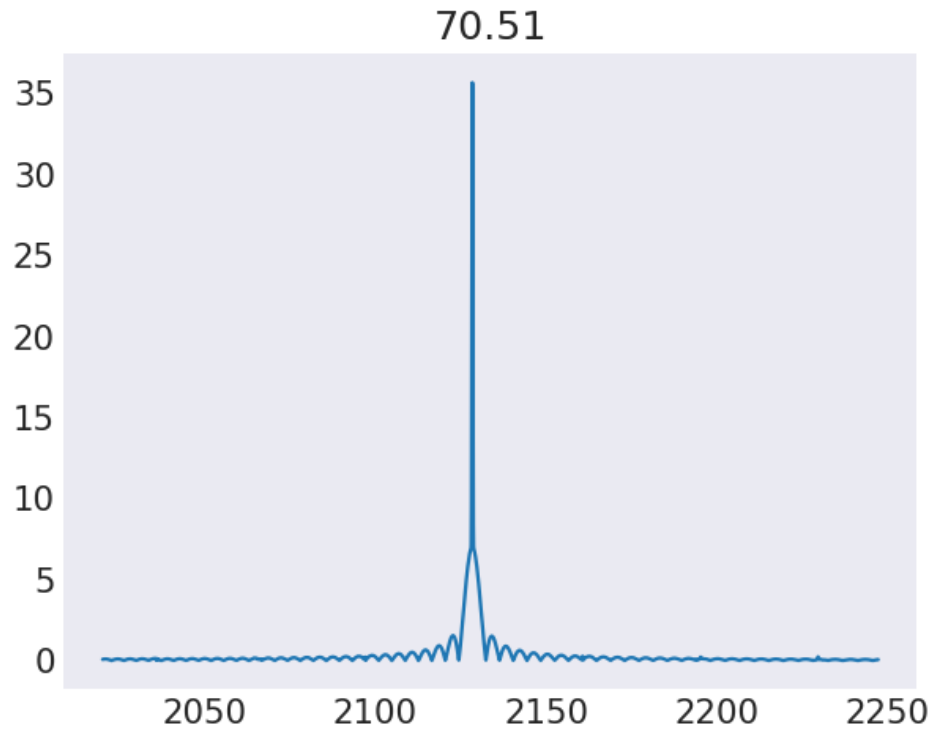

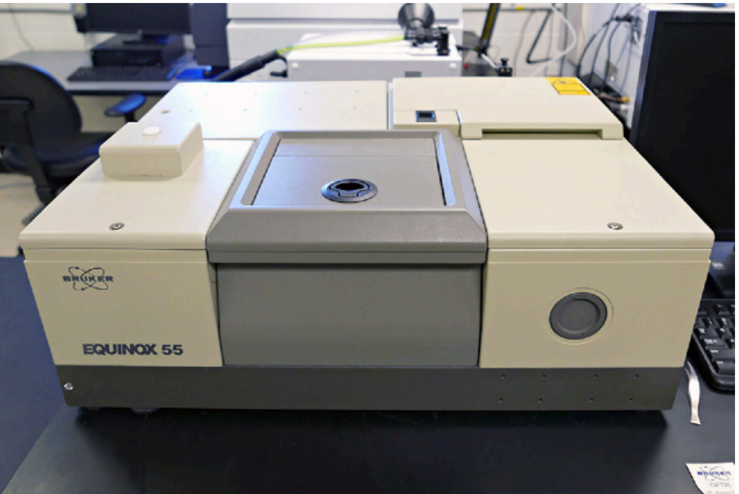

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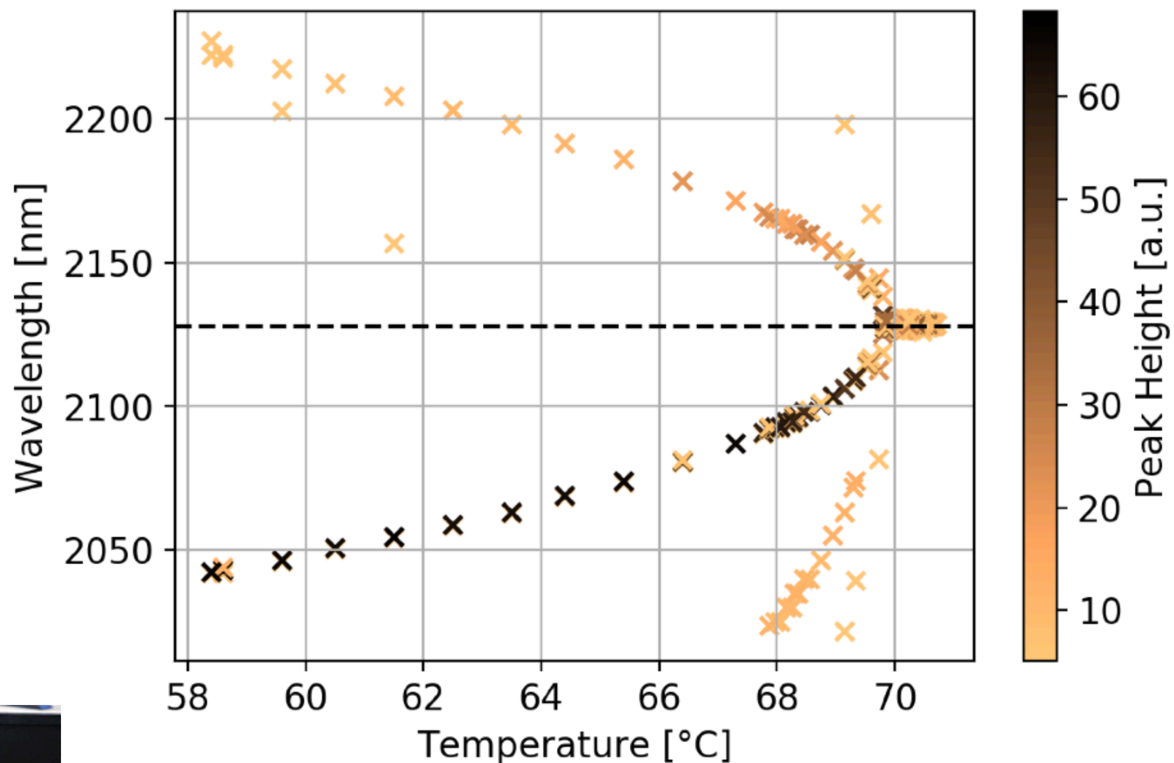

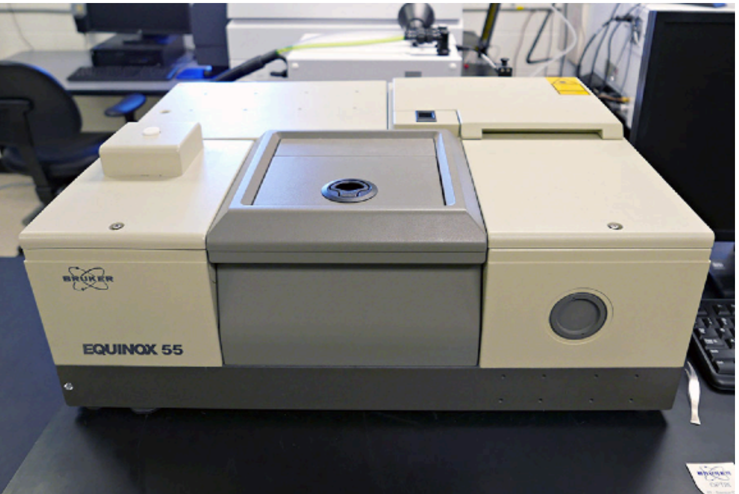

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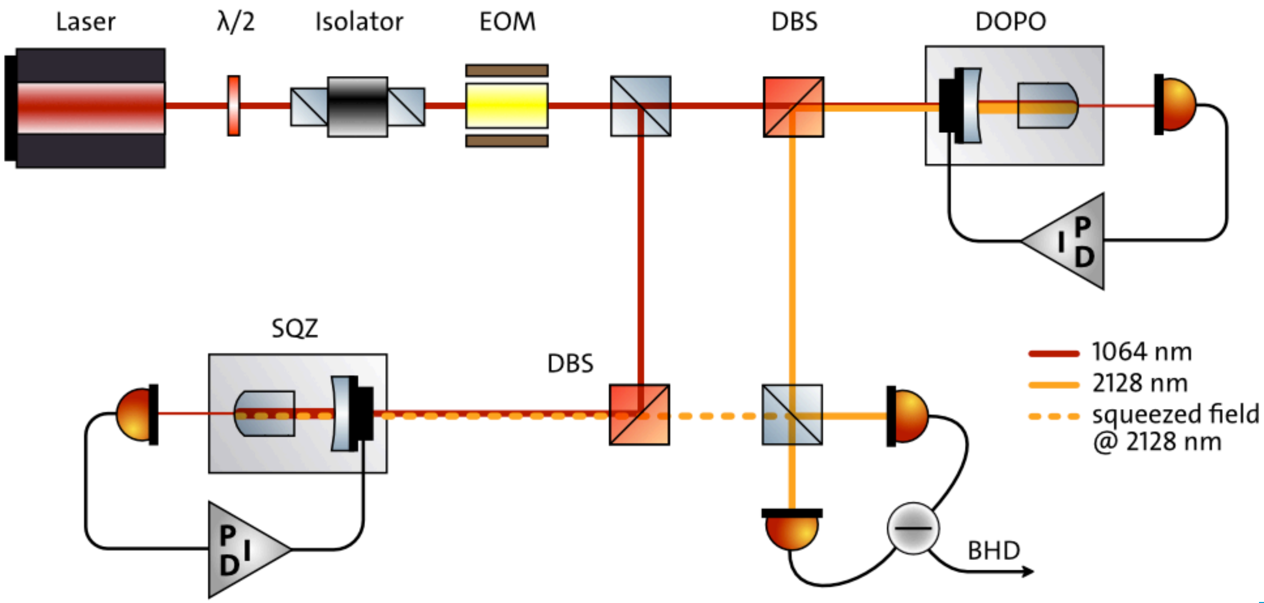
Next Steps

- further map out optimal operating regime for DOPO
- currently setting up confocal cavity to analyse degeneracy and/or remaining frequency differences that cannot be resolved with the FT-IR
- measure easily accessible characteristics such as intensity noise, compare with Mephisto pump laser
- set up second nonlinear cavity, produce squeezing



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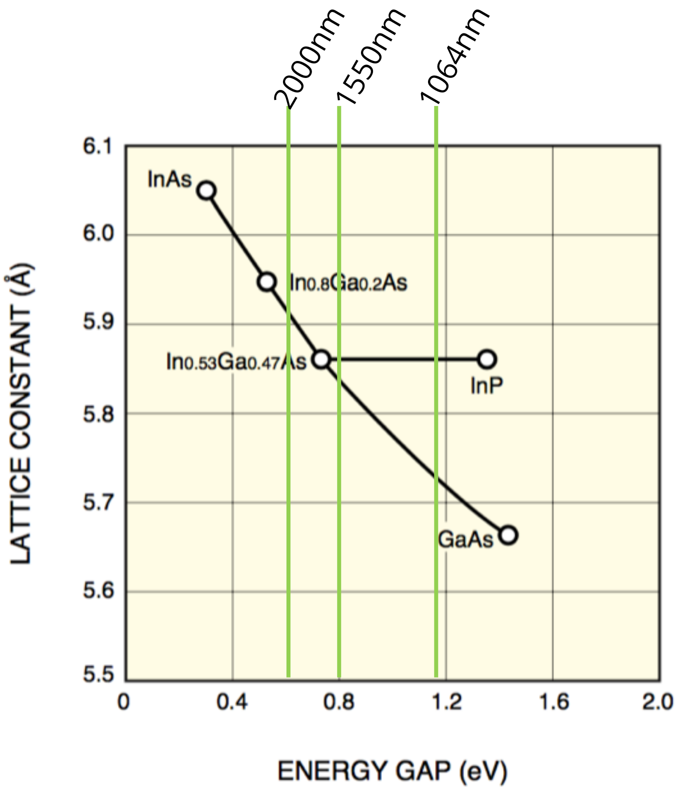
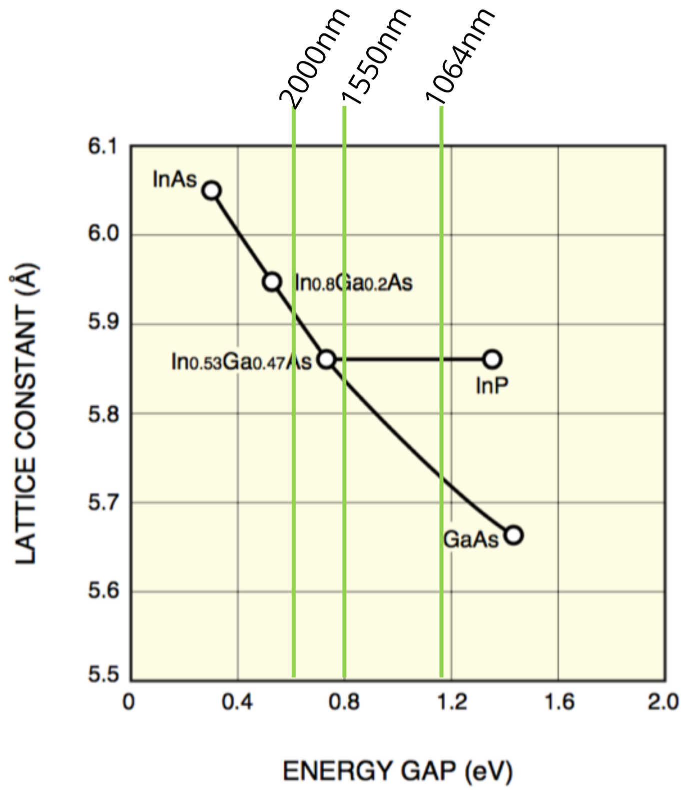
- Low-OH fused silica another cost driver (Infrasil 302, Corning 7979, ...)

Photodiodes



Photodiodes

- InGaAs has cut-off at around 1.7µm



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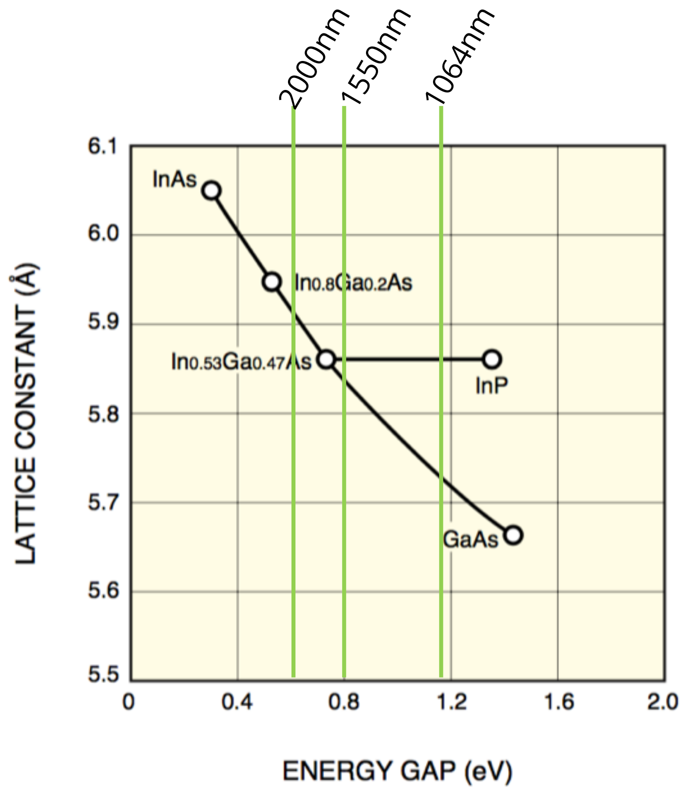
- Extended InGaAs available up to ~2.6µm
  - reduced Ga, more In
  - not lattice matched to InP, leads to trapped states at dislocations, which in turn give rise to large 1/f noise and dark current



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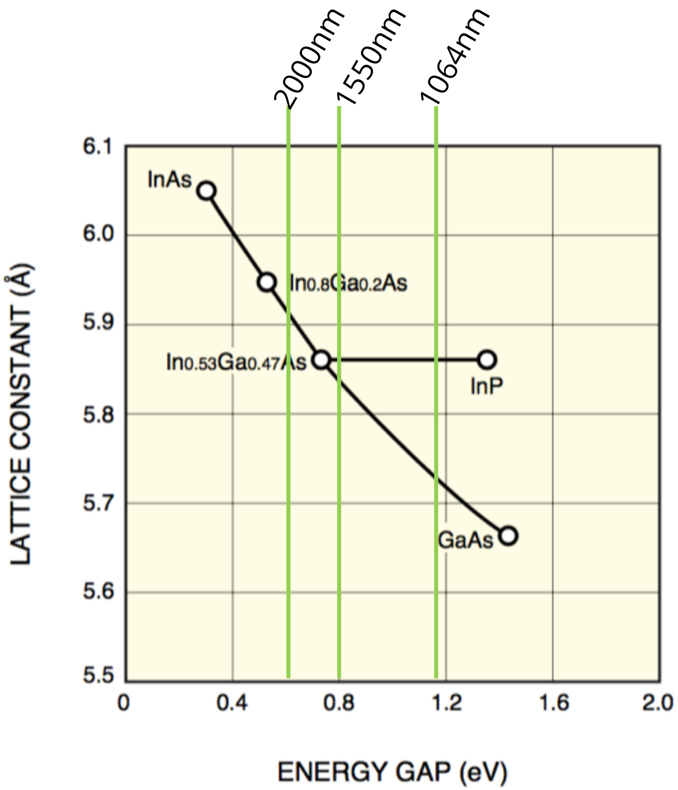
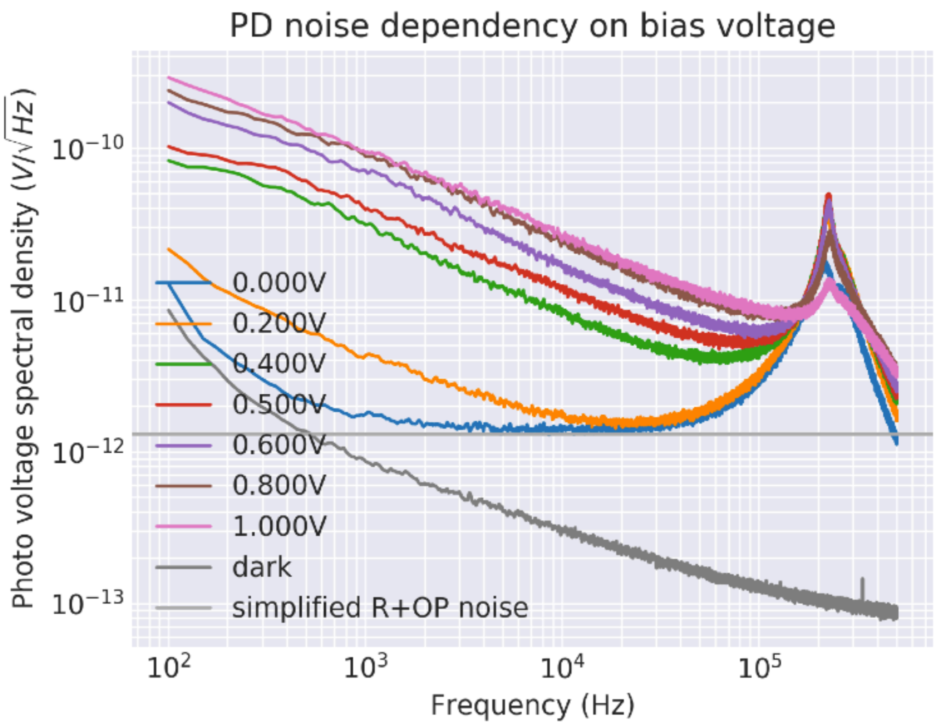
- Investigations by Joe Briggs et al. @ Glasgow, T1800491
  - characterisation of Ext-InGaAs PDs by different vendors
  - no improvement on noise for modest cooling
  - would need ~4.6µm of InGaAs for a QE of 99%, unlikely to be feasible



Example 1/f noise

- LaserComponents 2.4µm Ext-InGaAs PD, 500µm diameter
- operation with pretty much any reverse biasing leads to huge increase of 1/f noise



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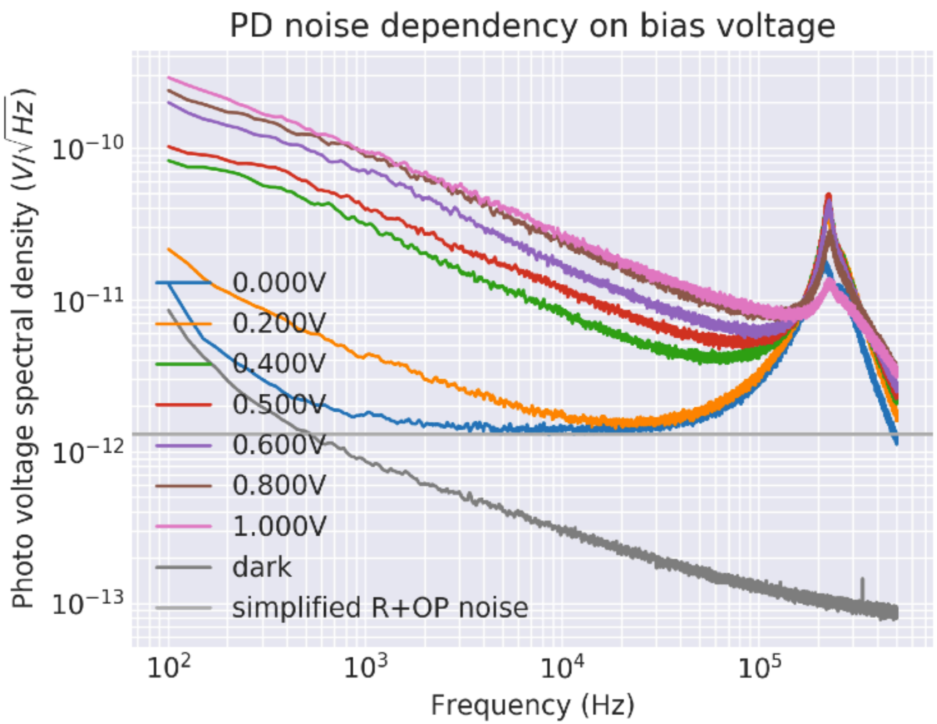


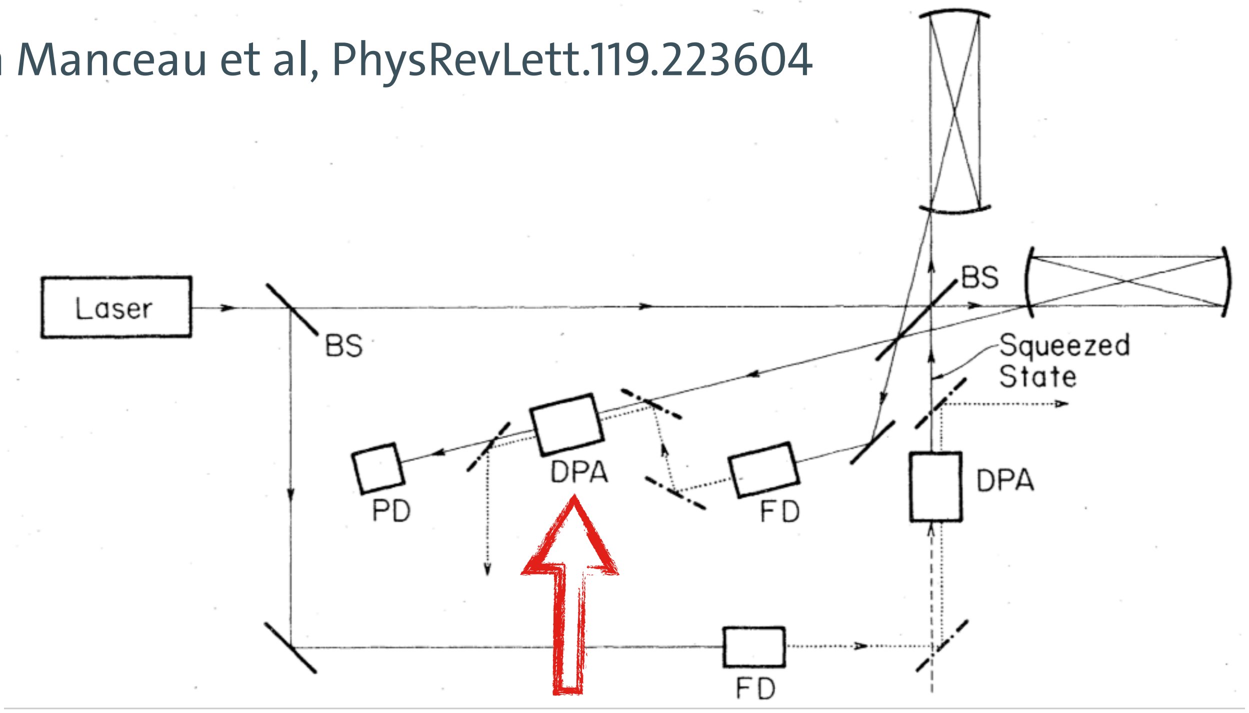
Other options:

- HgCdTe (MerCad)?
- InAs?
- ...?

What about quadrant PDs, bull's eye PDs, etc?

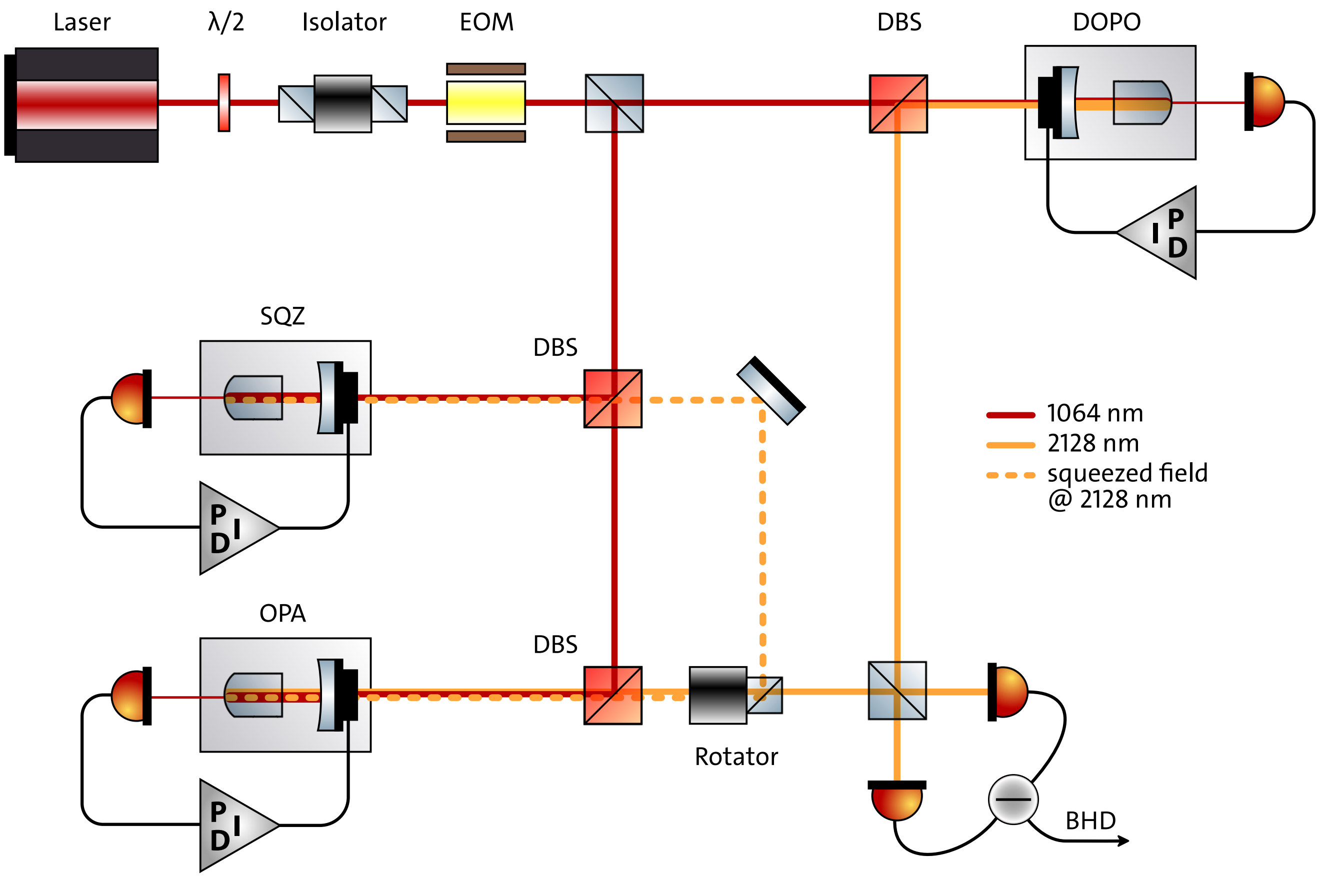
Compensating PD Efficiency with OPA

- Idea has been around since at least Caves' paper of 1981
- Amplify output signal + (quantum) noise to far above shot noise
- Afterwards, loss affects both signal and noise in the same way, so SNR is not affected by detection loss
- Demonstrated in Manceau et al, PhysRevLett.119.223604



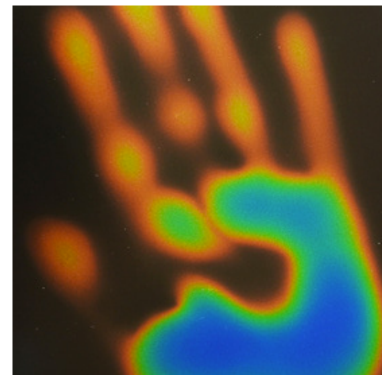
Compensating PD Efficiency with OPA

- Straight-forward extension of our 2µm setup, “just” add another OPA



Some Practical Issues

- No deal-breakers here, just annoying...
- Beam-finder cards are generally thermal only
  - slow, immediately saturated, sensitivity depends on lab temperature



- cameras expensive (e.g. zinc-antimonide covers 1.5-5µm); for beam finding thermal imaging cameras can be somewhat useful
  - still slow (thermal, they don't see 2µm directly)
  - surprisingly cheap (for low resolution) nowadays

Summary

- developments on coating thermal noise indicate that combining silicon substrates with amorphous silicon coatings could satisfy 3G requirements, but absorption dictates shift to a wavelength of around 2µm
- technological pathfinding and challenges under way for
  - lasers
  - photo detection
  - squeezing
- slow but steady progress on understanding OPO for 1064 → 2128nm
- setup will be expanded for squeezing and QE compensation