LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Spectroscopic Real Time Temperature Diagnostic for Laser Heated Thin Foils

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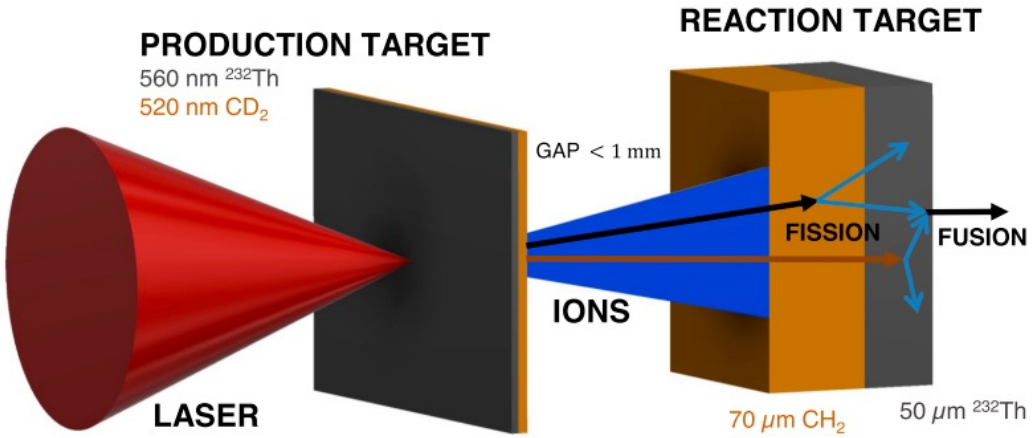
CALA

Why accelerate heavy ions?

Fission-fusion reaction mechanism



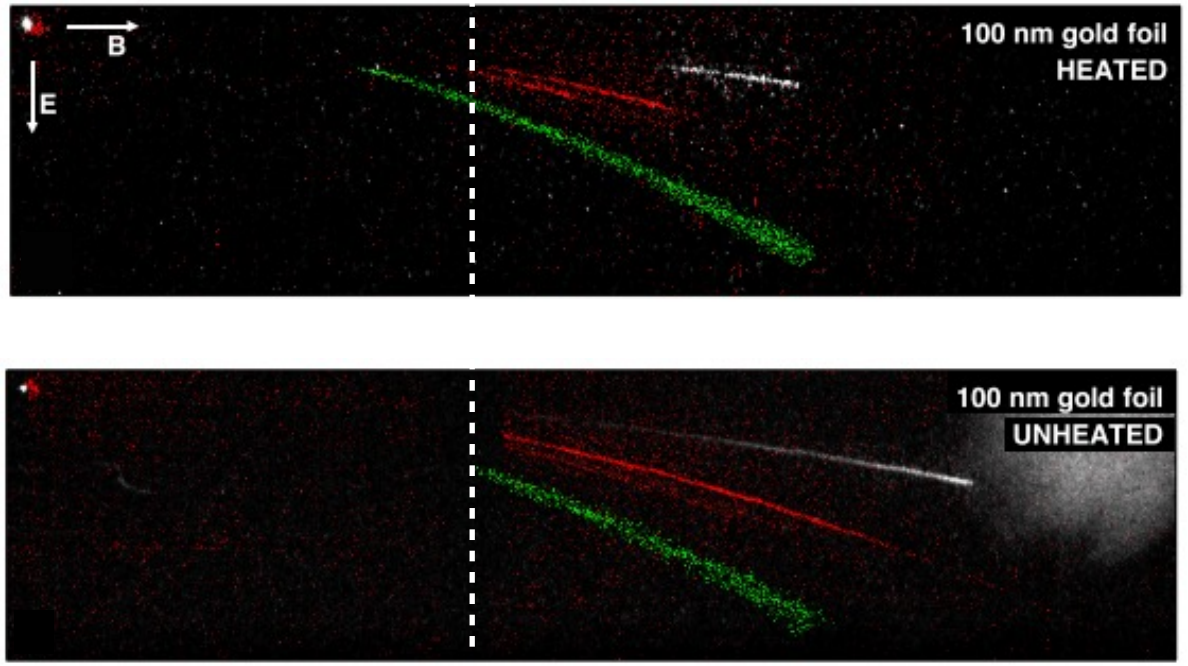
- Rapid neutron capture (r-process) nucleosynthesis of heavy elements

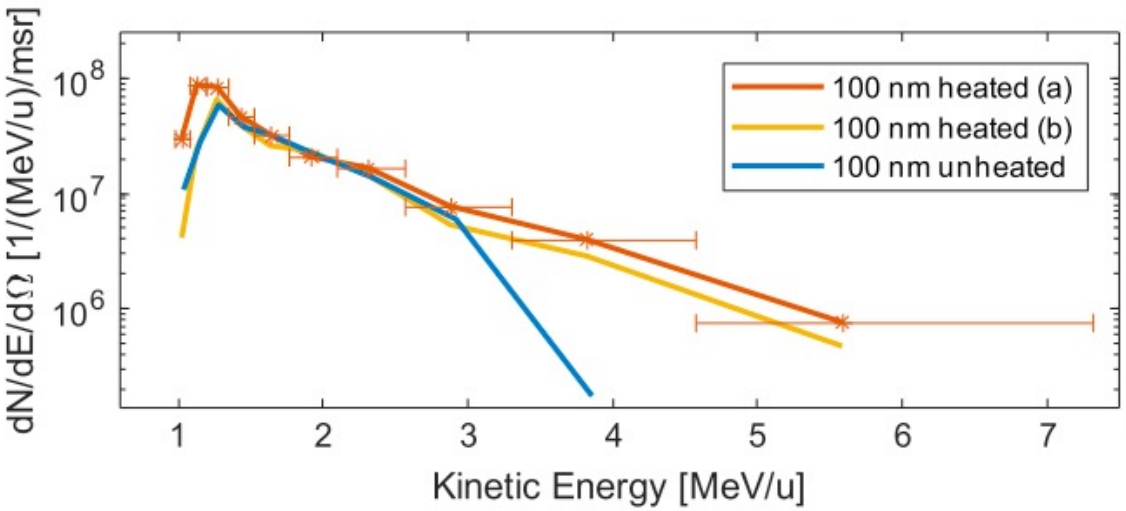
1. Production of laser-accelerated ions
2. Fission of $^{232}\mathrm{Th}$ ions
3. Fusion of neutron-rich light fission fragments

- Ions accelerated with very high density, enabling this experiment
- $^{232}\mathrm{Th}$ energy needs to exceed fission barrier at 7 MeV/u

D. Habs et al., Appl. Phys. B 103, 471-484 (2011)
F.H.Lindner, Nucl. Instrum. Meth. B 302, 354-357 (2017)

Experiment at Texas Petawatt Laser (TPW) 2017



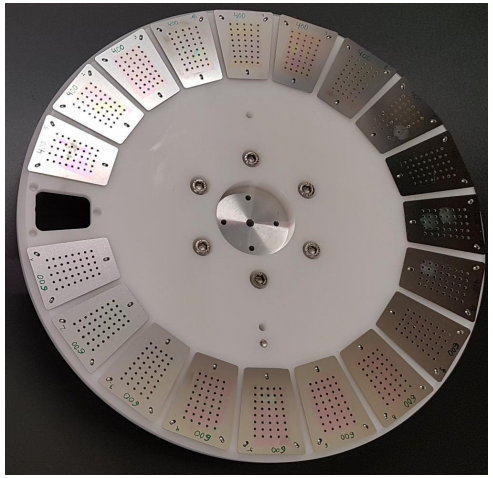


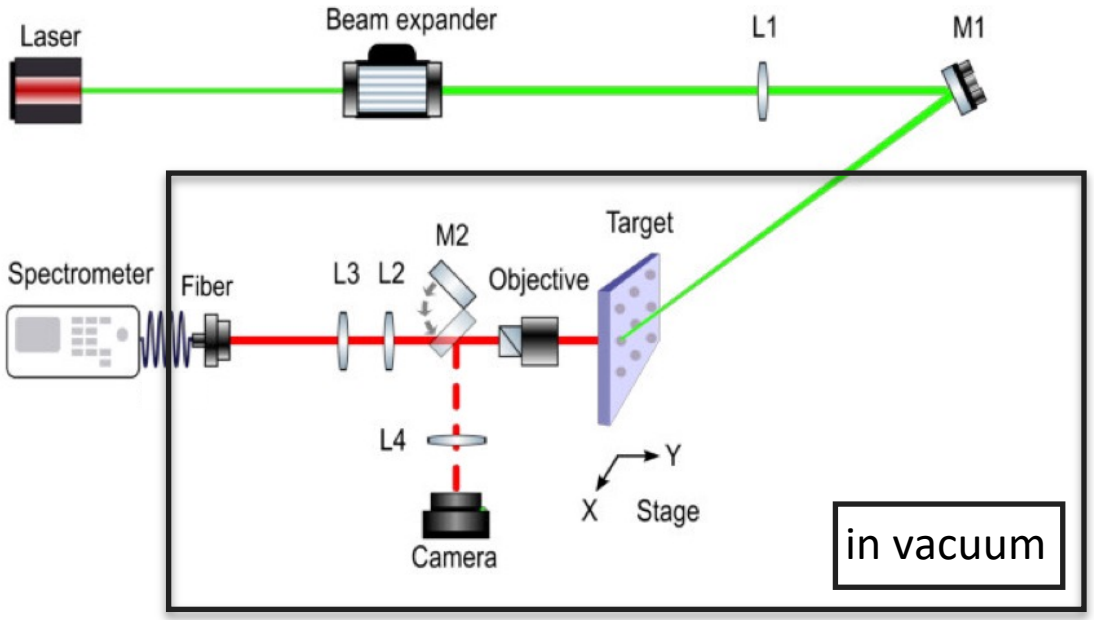
- Particles with higher charge-to-mass ratio more efficiently accelerated
- Evaporative target heating to reduce acceleration of lighter ions

F.H. Lindner et al., Phys. Plasm. Contr. Fusion 61, 055002 (2019)

Set up

- Heating laser Nd:YAG @ 532 nm
- Tunable cw output power up to 3 W
- IR thermal radiation captured via NIR spectrometer
- Target temperature fitted via Planck's law





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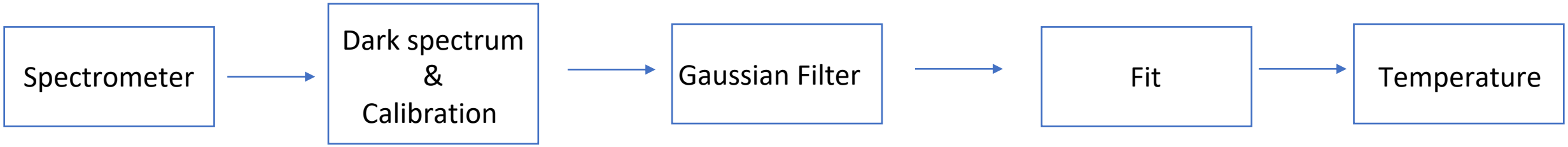
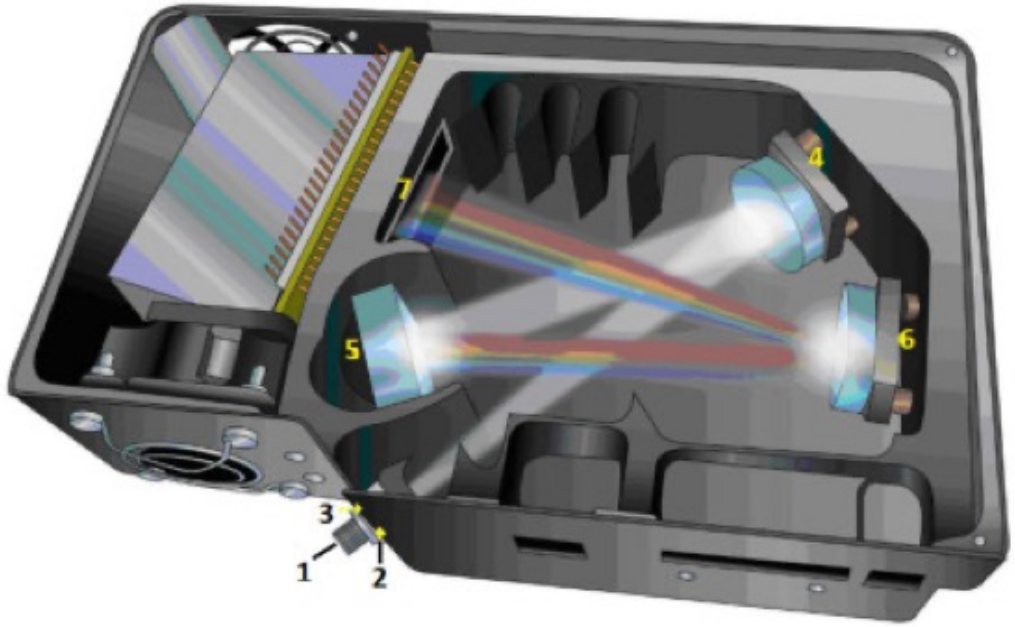
Temperature measurement



Temperature measurement

Spectrometer → Dark spectrum & Calibration → Gaussian Filter → Fit → Temperature



NIRQuest spectrometer	
Range	900-2500 nm
Slit size	200 µm
Optical resolution	~25 nm

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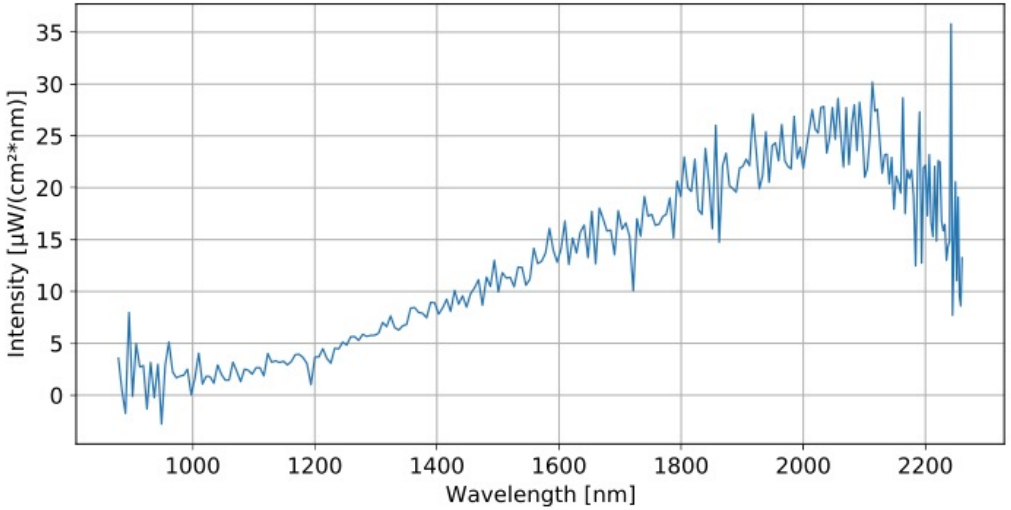
Temperature measurement

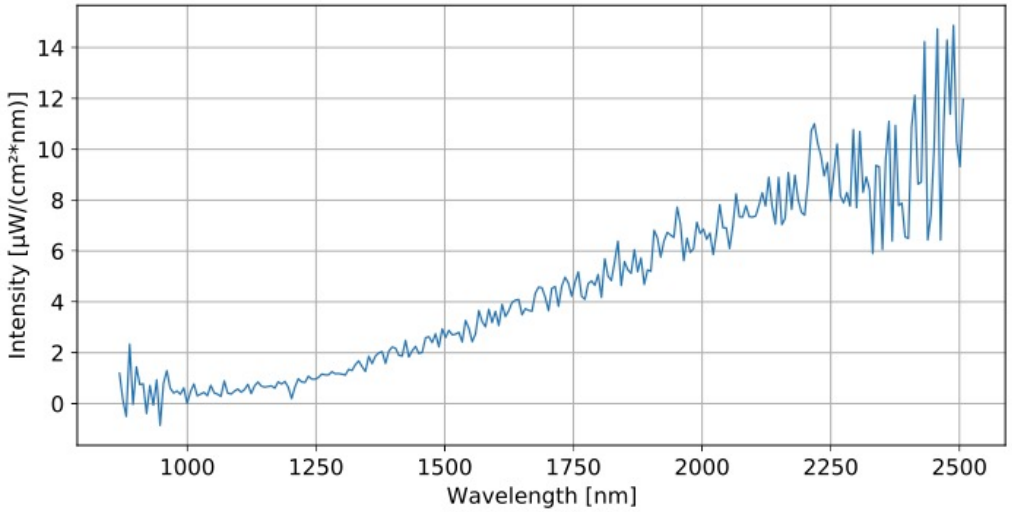
Spectrometer → **Dark spectrum & Calibration** → Gaussian Filter → Fit → Temperature

$$S_{\text{realsurface}}(T,\lambda) \simeq S_{\lambda,\text{graybody}}(T) = \varepsilon \cdot S_{\text{blackbody}}(T)$$

$$I(\lambda,T,a,b) = a \cdot \left(\frac{2hc}{\lambda^5} \cdot \frac{1}{\exp\left(\frac{hc}{\lambda k_B T}\right)-1}\right) + b$$



Wrong calibration coefficients



Right calibration coefficients

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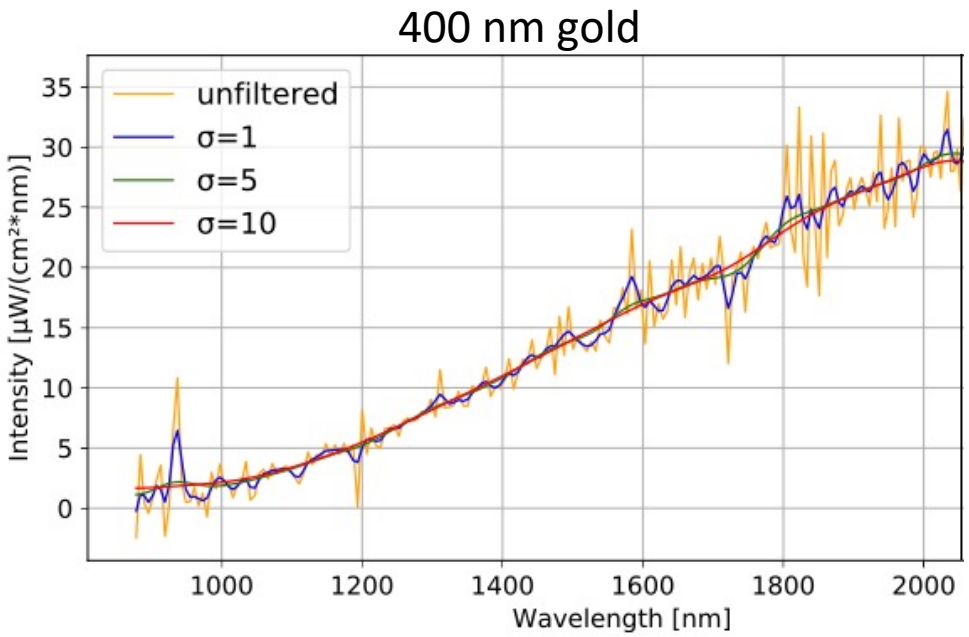
Temperature measurement

Spectrometer → Dark spectrum & Calibration → **Gaussian Filter** → Fit → Temperature

- Gaussian filter is applied to smoothen the spectrum



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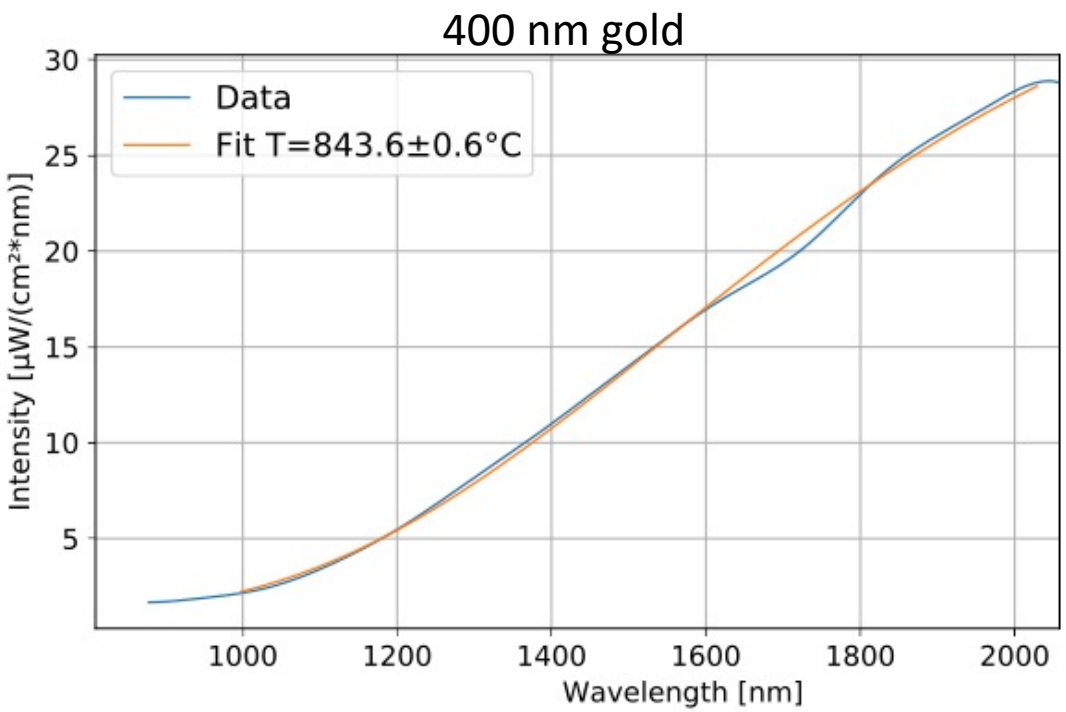
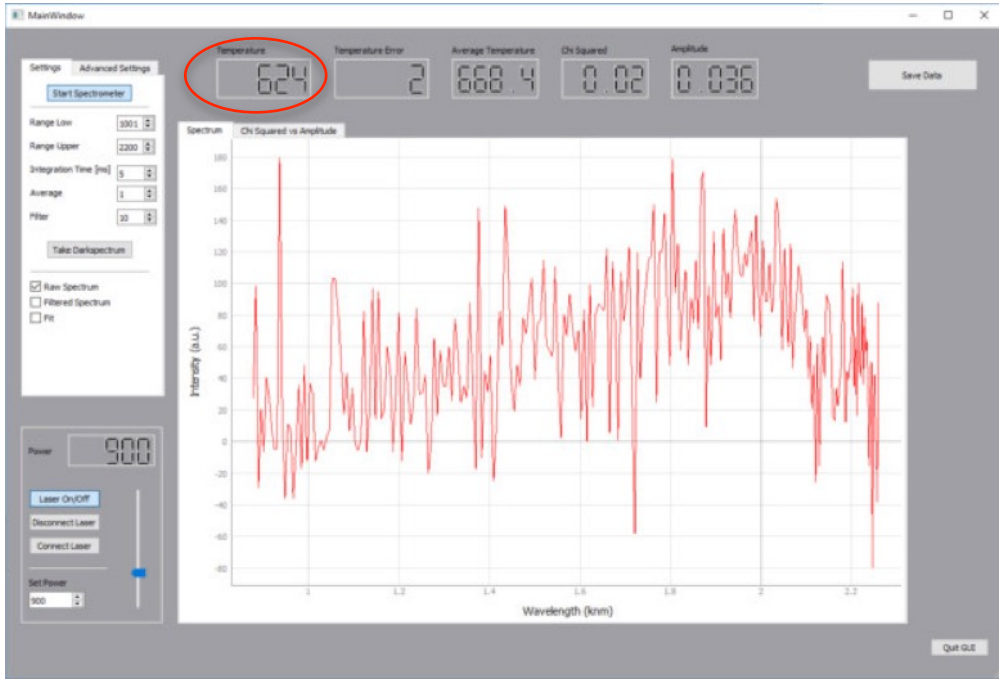
Temperature measurement

Spectrometer → Dark spectrum & Calibration → Gaussian Filter → Fit → Temperature





- GUI gives real time T

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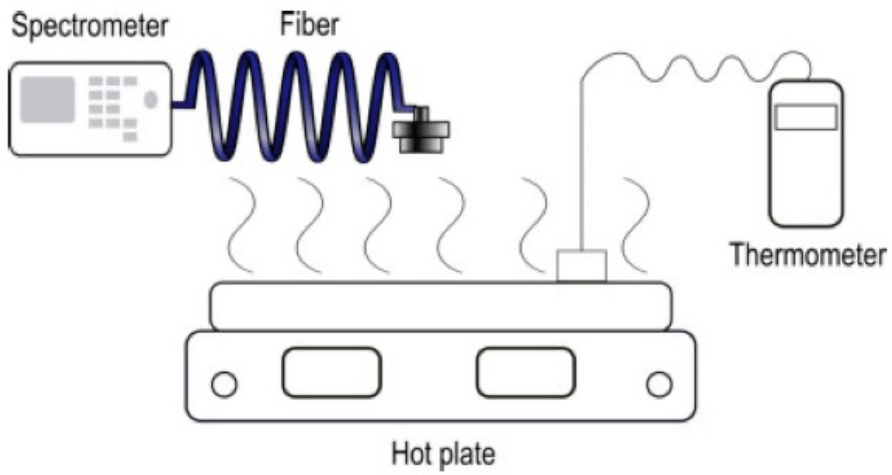
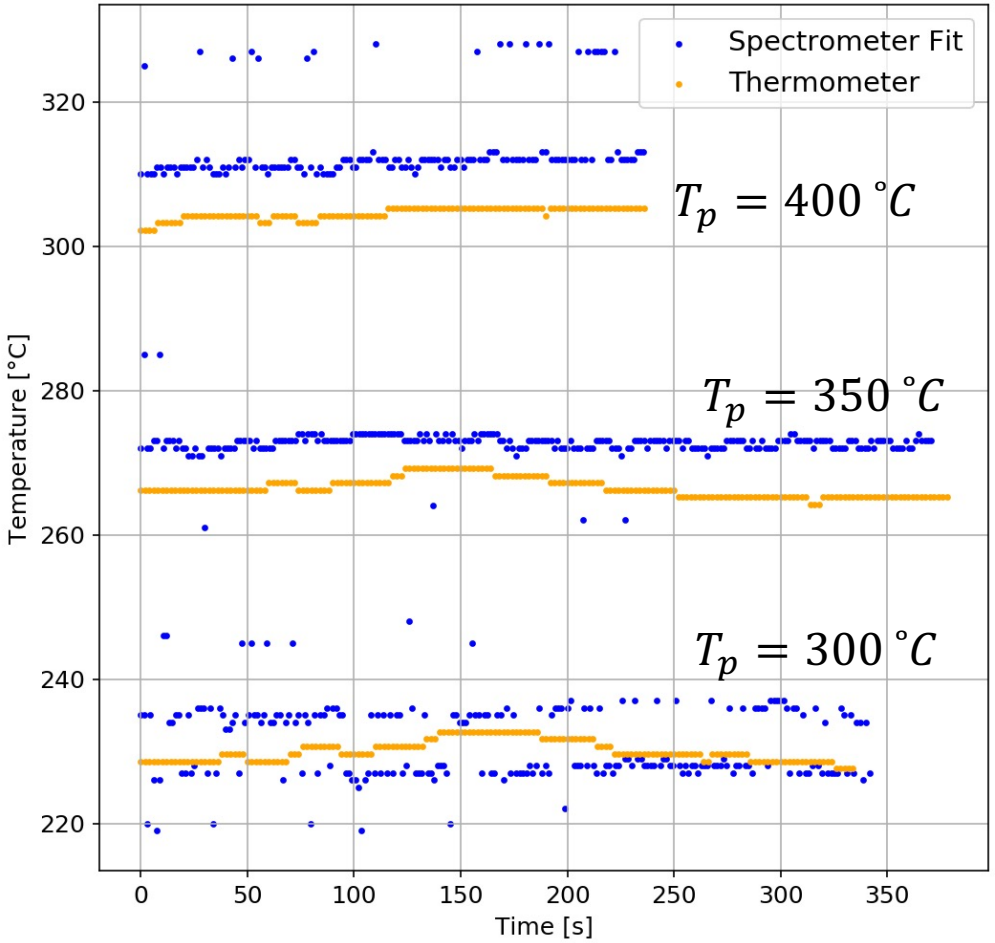
Validation





- Cross check with Thermometer on hot plate up to 400 ˚C
- Thermocoupled with black foil for defined emissivity
- Standard deviation within 10 ˚C
- Stable over time

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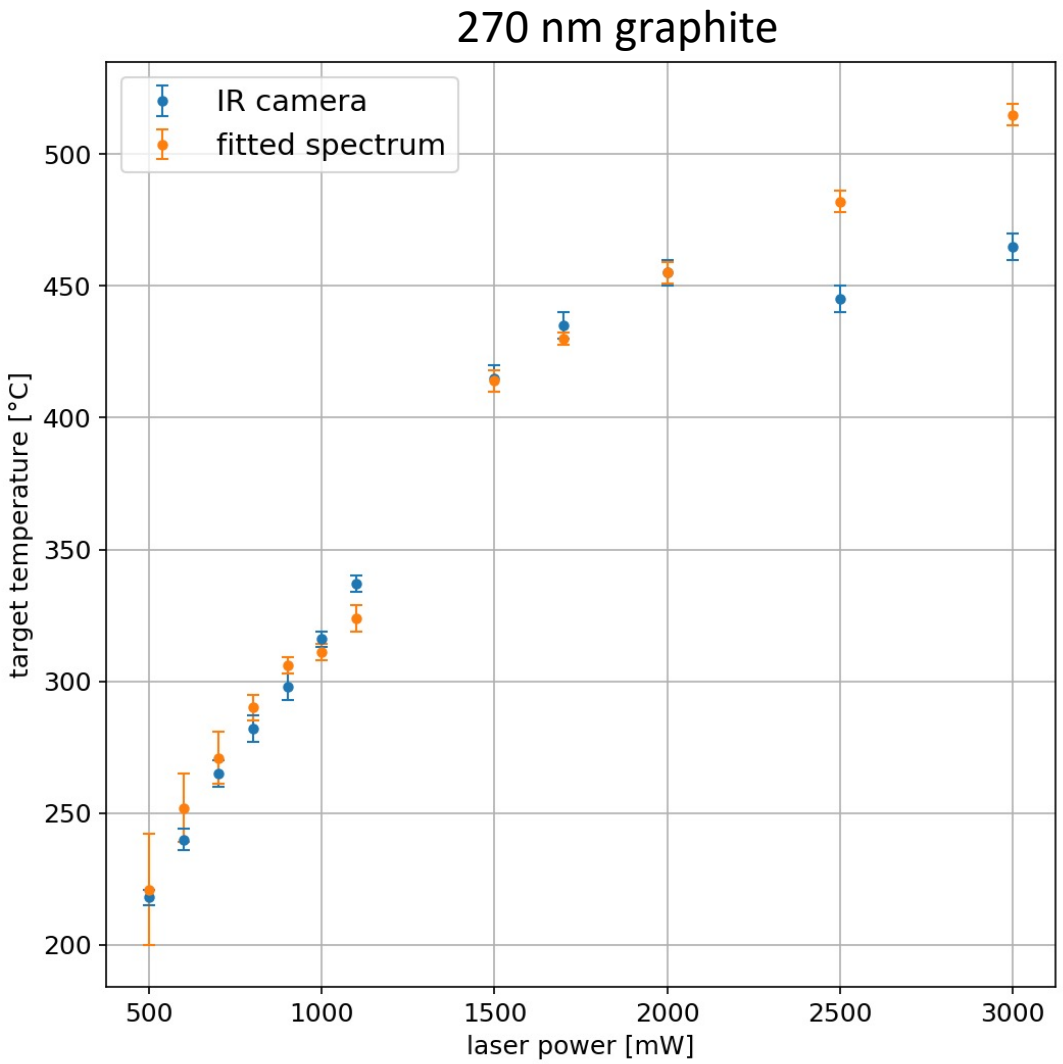
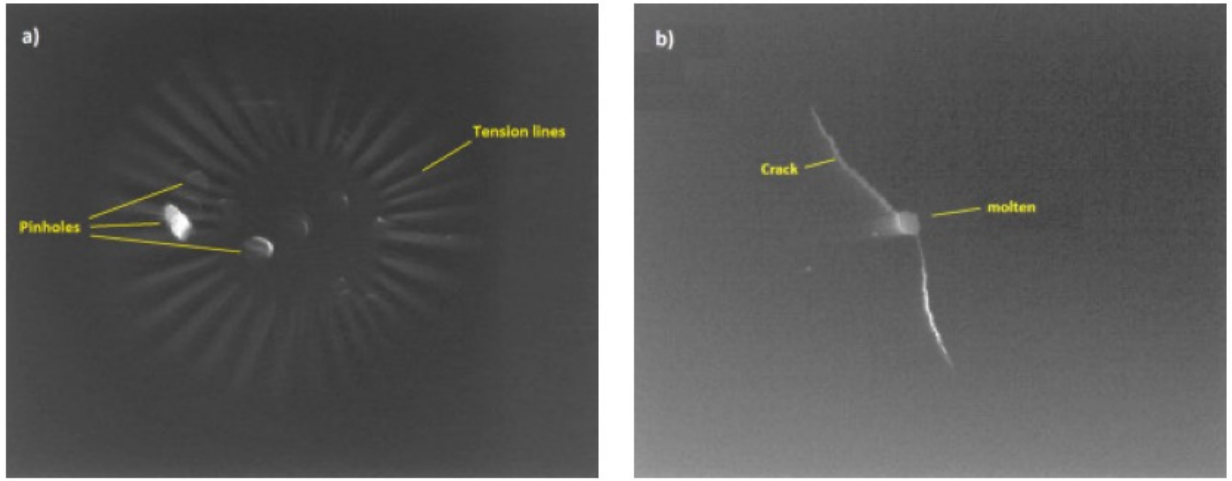
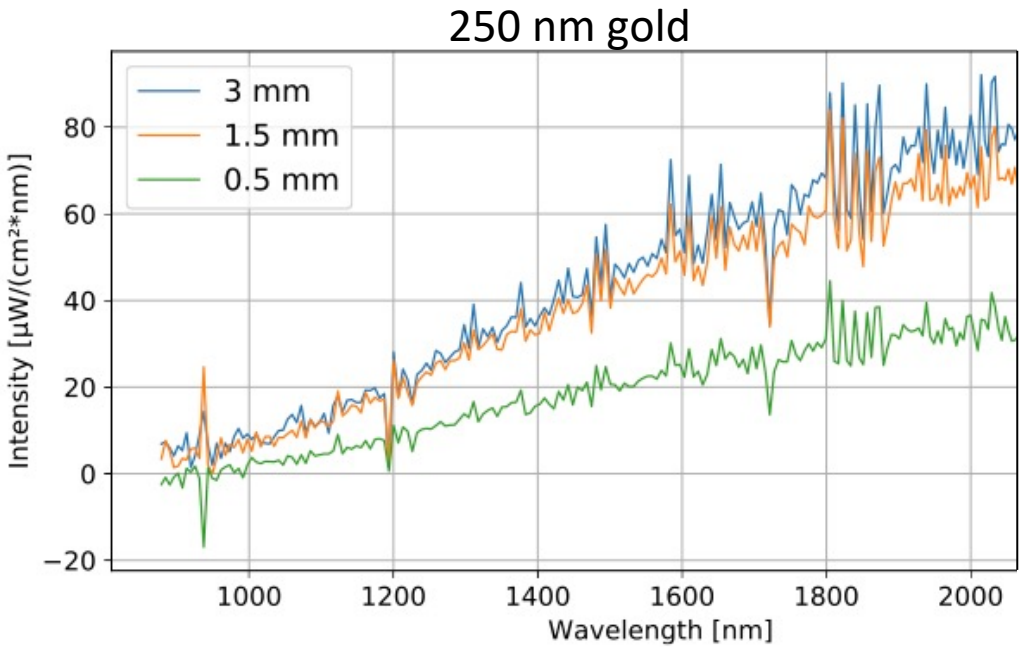
Validation

- Cross check with IR camera and heating laser on graphite target
- Very good agreement of both measurement techniques
- Gold shows similar behavior but starts breaking earlier due to thermal stress



Measurements with gold





- If laser power not distributed homogeneously on target, it can break from thermal stress
- For elliptical beam of 1.5 x 4 mm target with inner diameter of 3 mm broke before reaching 1000 ˚C

- Signal strength varies for different target diameters
- Strongest signal for largest target size

→ Inner target diameter of 1.5 mm will be used for future experiments

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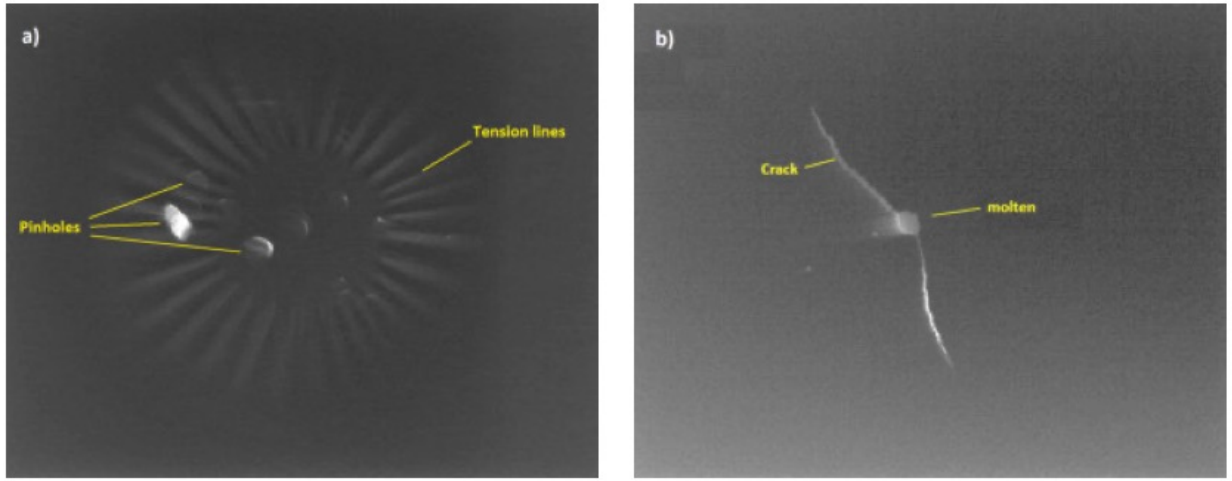
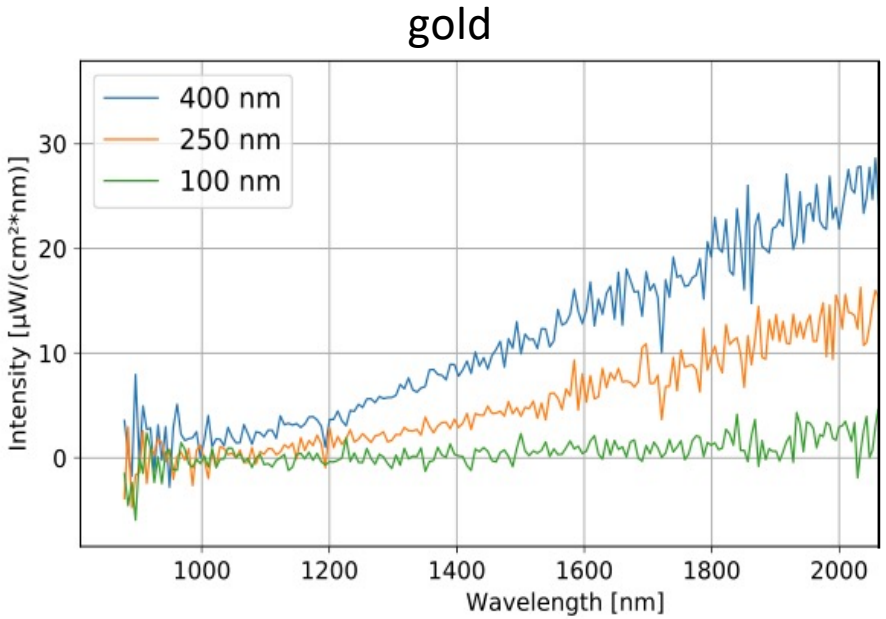
Measurements with gold





- If laser power not distributed homogeneously on target, it can break from thermal stress
- For elliptical beam of 1.5 x 4 mm target with inner diameter of 3 mm broke before reaching 1000 ˚C

- Targets heated close to breaking point
- Signal strength varies for different thickness

→ Inner target diameter of 1.5 mm will be used for future experiments

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Conclusion and Outlook

Conclusion

- Setup for laser target heating built and tested in air
- Evaluation routine established to determine foil temperature from IR Planck spectrum
- Heating laser and spectrometer integrated into setup

Outlook

- Establish setup in chamber
- Evaluate Backreflex protection for heating laser
- Integrate heating into automated target system and save to database
- Find optimum target temperature to maximize ion energy