# Operational optimizations for TES detectors at a femtosecond X-ray laser

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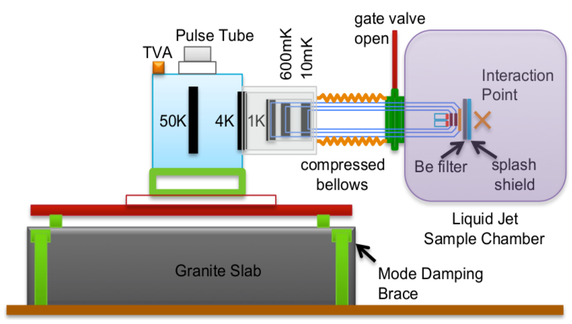
## Abstract

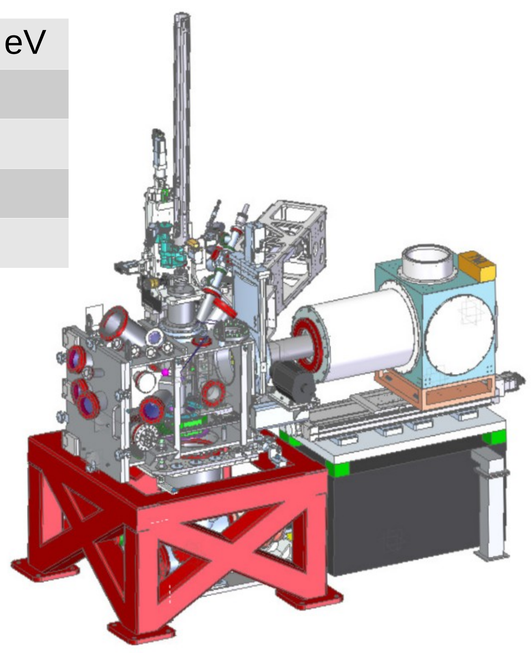
Transition-edge sensor (TES) microcalorimeters have found success as X-ray detectors at synchrotron light-sources, due to a unique combination of high collecting area and good energy resolution. However, the upcoming generation of free-electron lasers, such as the Linac Coherent Light Source II (LCLS-II), will be orders of magnitude brighter and faster than current sources, potentially leading to severe pulse-pileup issues. We will demonstrate that it is possible to mitigate pulse pile-up using simple X-ray filters, and take advantage of the substantial increase in X-ray flux.

## Transition-Edge Sensors in development enable LCLS-II science

### TES Design Targets

| | |
|---|---|
| Energy Resolution | dE ~ 0.5eV @ 500 eV |
| Number of Pixels | 1000 |
| Total Active Area | 40 mm² |
| Count Rate | 900 kcps |
| Energy Range | 200 – 1600 eV |



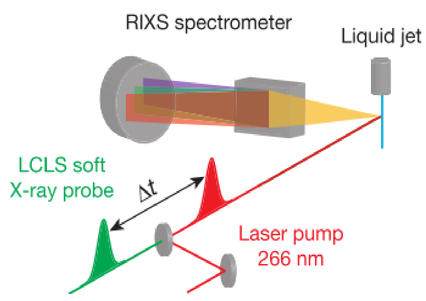



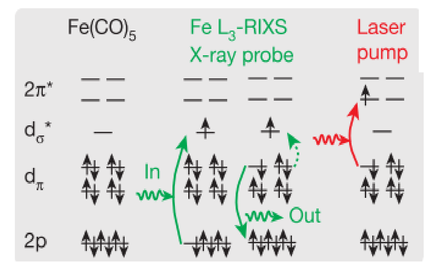
### LCLS-II Features

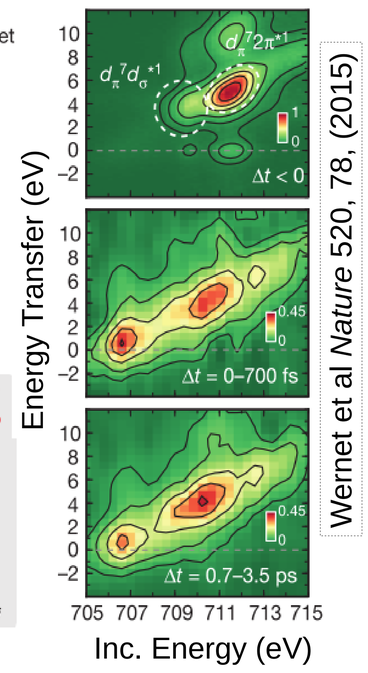
- Bright ($10^{13}$ γ/pulse)
- Ultrafast (50 ps pulses)
- Pulse rate (300 kHz)

### TES Enables

- Dilute samples
- Faster data collection
- Broad energy range
- Push-button operation



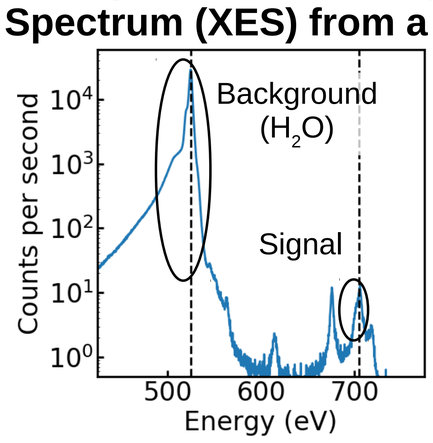



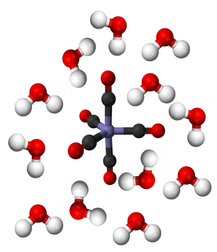




## High Background

**1:10000 signal-to-background ratio**

**Representative X-ray Emission Spectrum (XES) from a dilute sample**



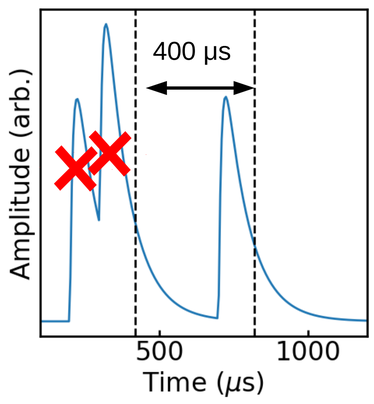



Liquid samples are mostly water!

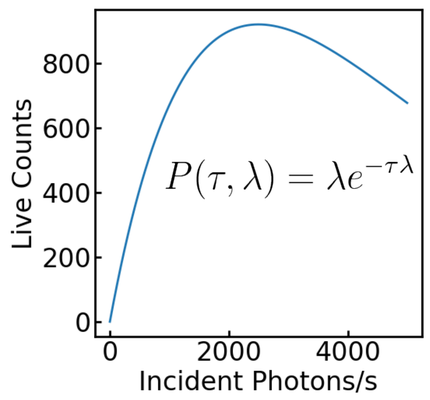
## High Flux

**LCLS-II flux must be *reduced* to stay under maximum count rate**

**Simulated Pulses**



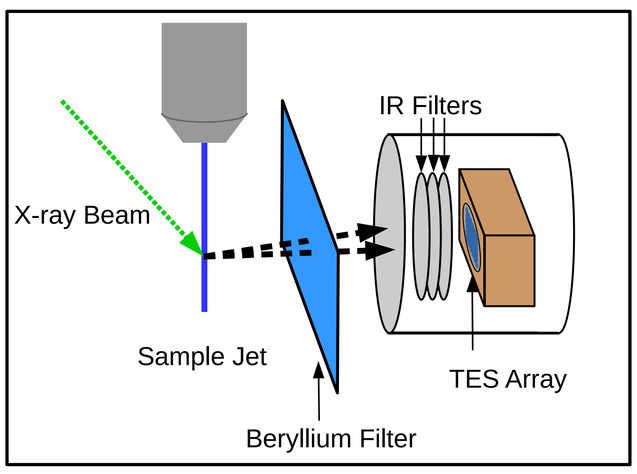

**Live Count Rate**



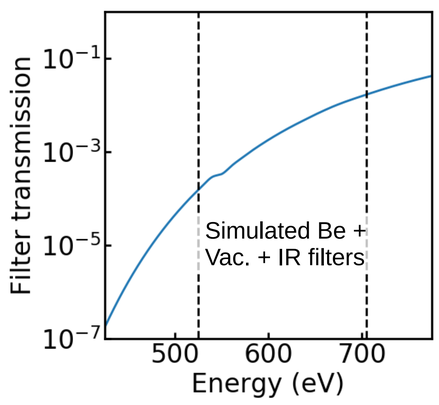

**Unfiltered Count Rate** (per pixel)

| | |
|---|---|
| Raw Incident γ/s | 10,000,000 γ/s |
| Dead-time, τ | 400 μs |
| Optimal Incident γ/s | 2500 γ/s |
| Live counts | 919 γ/s |
| Background counts | 918.9 γ/s |
| Signal counts | 0.1 γ/s |

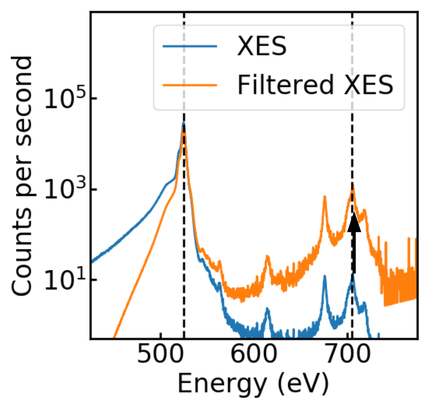
## Maximize signal rate with beryllium transmission filter




**6 μm beryllium Transmission**




**Simulated effect on XES**




**LCLS-II Flux can be *filtered* for a 30x improvement in signal**

| | |
|---|---|
| Filtered Incident γ/s | 2500 γ/s |
| Optimal Incident γ/s | 2500 γ/s |
| Live counts | 919 γ/s |
| Background counts | 916 γ/s |
| Signal counts | 3 γ/s |

## Conclusion

**For high-flux, high-background X-ray applications such as LCLS-II, TES detectors work best in concert with a transmission filter to lower the overall signal**

## Acknowledgements