Multidimensional Optical Spectroscopy for Nonproliferation Measurements

MTV Kickoff Meeting

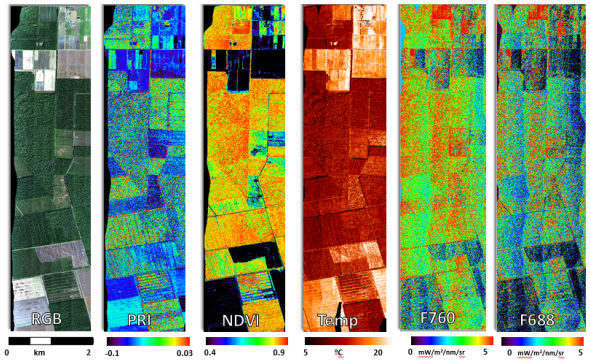
May 21, 2019

Igor Jovanovic
University of Michigan

Introduction and Motivation

- Nonproliferation detection relies on a broad range of technologies, including radiation detection, seismology, infrasound, optical spectroscopy, and analysis of big data analytics
- A subset of these technologies takes the advantage of selectivity, favorable propagation properties, and generous statistics of optical photons for proliferation detection
- The major advances in photon generation, manipulation, and detection offer a strong case for innovative use of optical techniques in nonproliferation context

Hyperspectral imaging

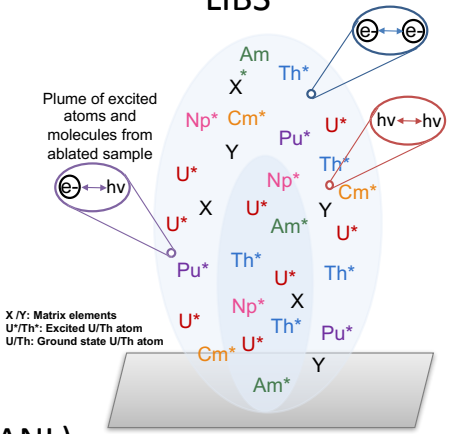


(NASA)

ICP-MS

(Perkin Elmer)

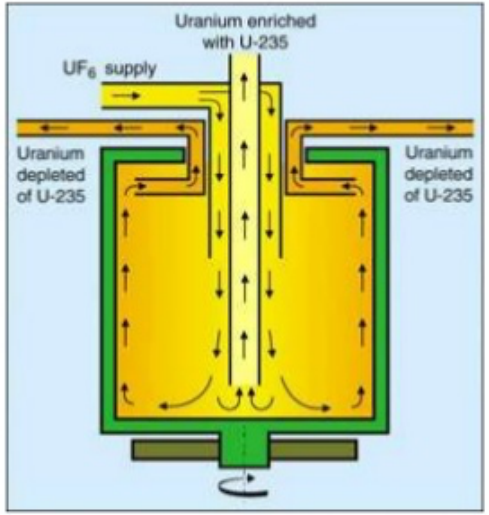
LIBS



(LANL)

Mission Relevance

Detect and monitor nuclear fuel cycle

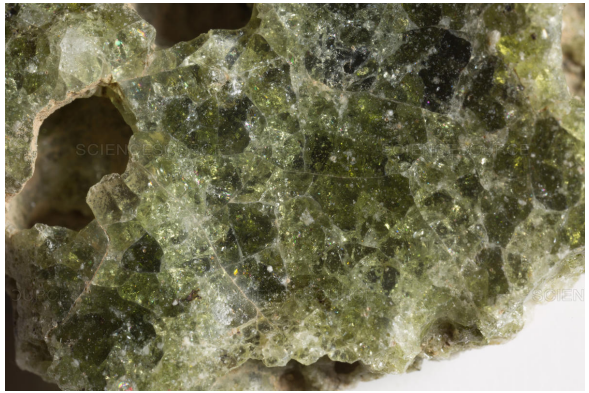


Detection of UO_2F_2

Detect diversion of special nuclear material

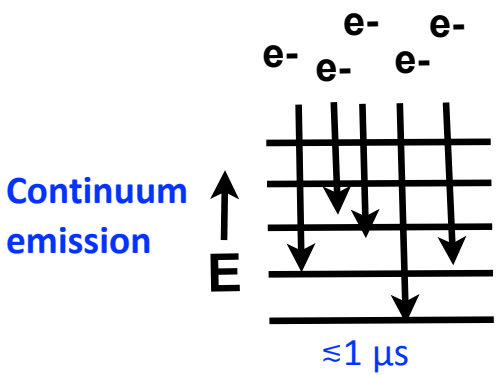
Rapid detection of uranium and its isotopes

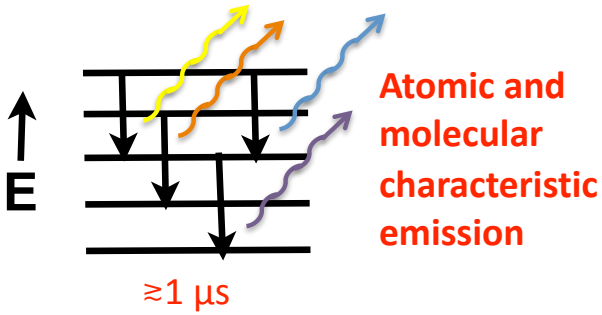
Improve the speed, accuracy, confidence, and specificity of nuclear forensics analytical techniques

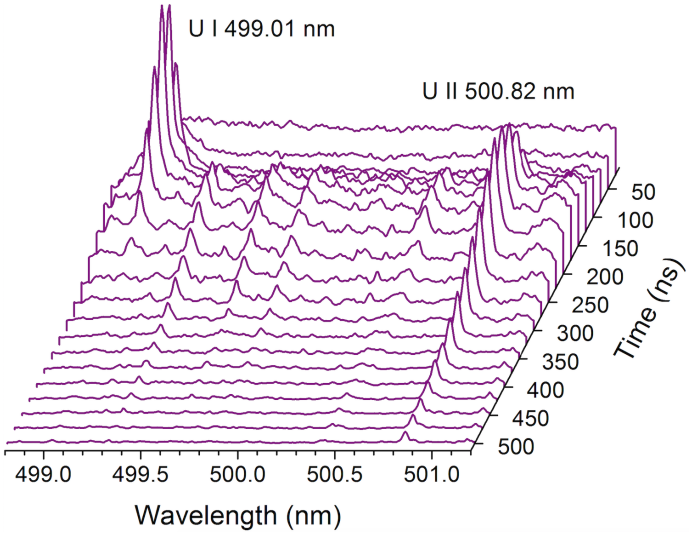


Detection of a wide range of elements and compounds

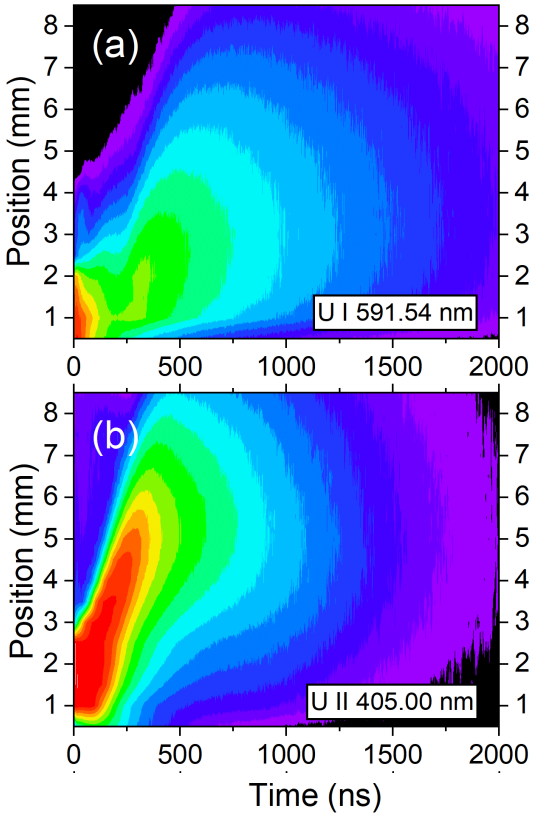
Optical signatures from laser-produced plasmas temporally and spatially dependent





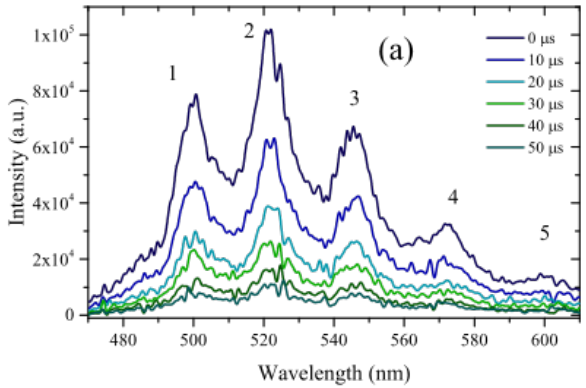


Courtesy: M. Burger and P. K. Skrodzki

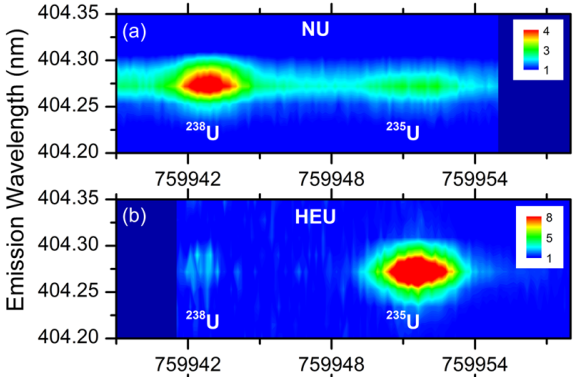


Examples of optical signature generation

Spectral- temporal



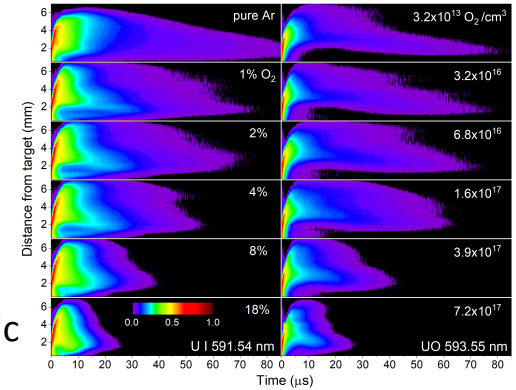
P. J. Skrodzki et al., Sci. Reports 8, 11629 (2018)



M. C. Phillips et al., Sci. Reports 7, 3784 (2017)

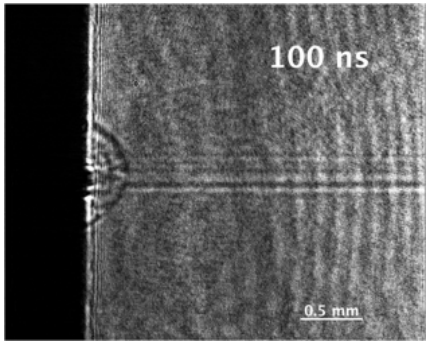
Spatio-temporal

Atomic



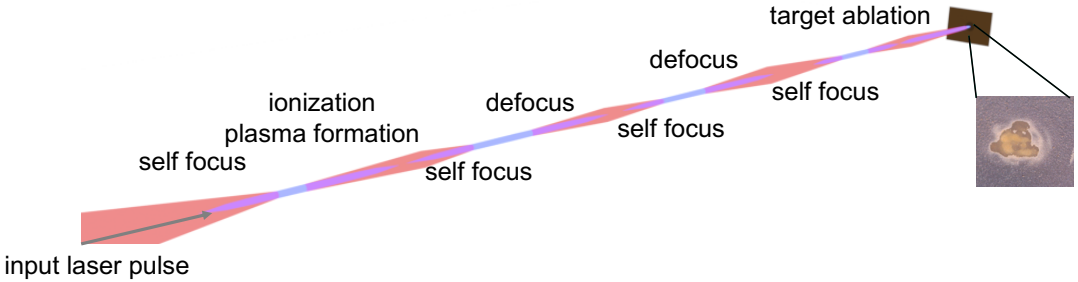
Molecular

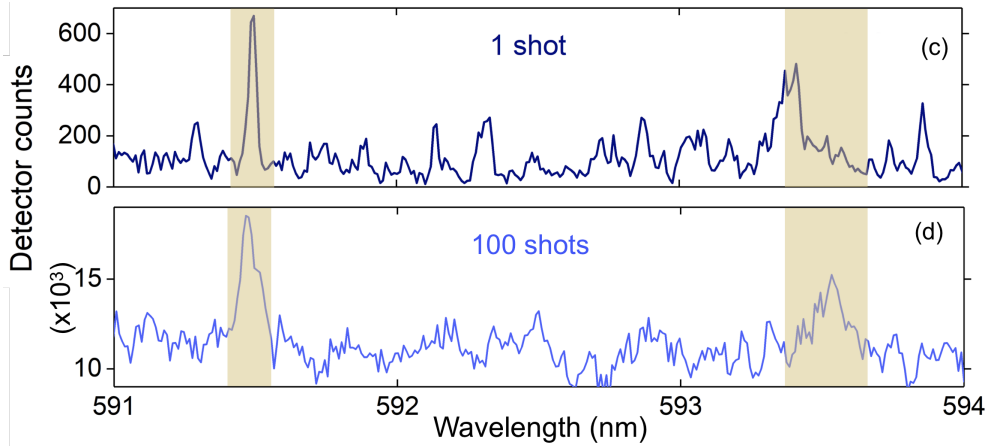
Courtesy: P. Skrodzki



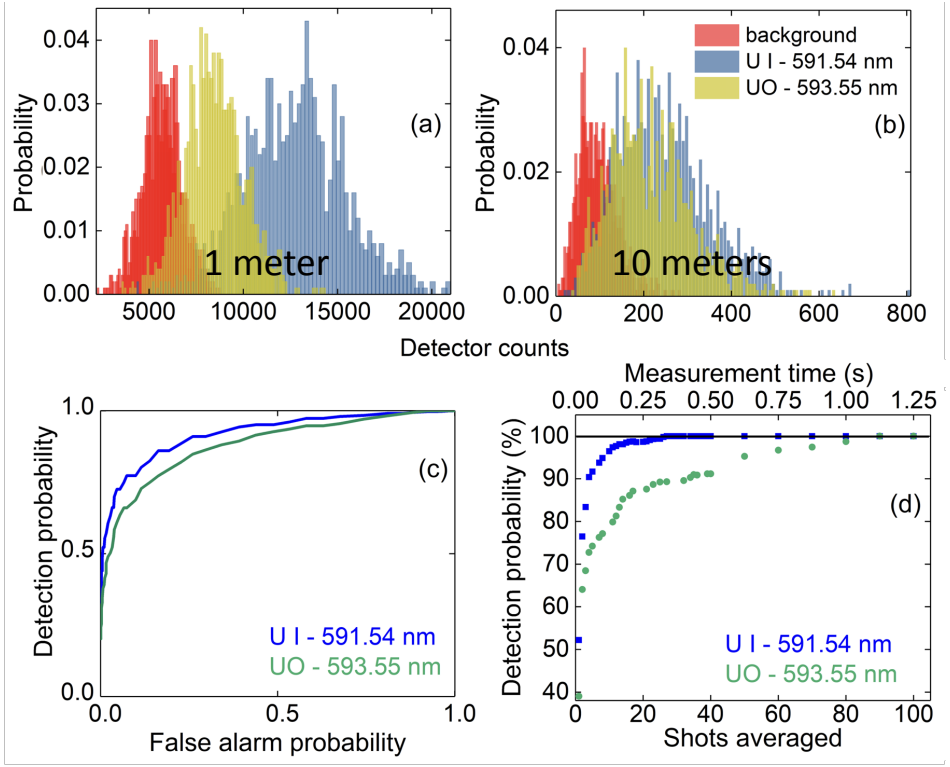
P. J. Skrodzki et al., Sci. Reports 7, 12740 (2017)

Multi-signature detection of uranium at ten meters using a laser filament in a single shot



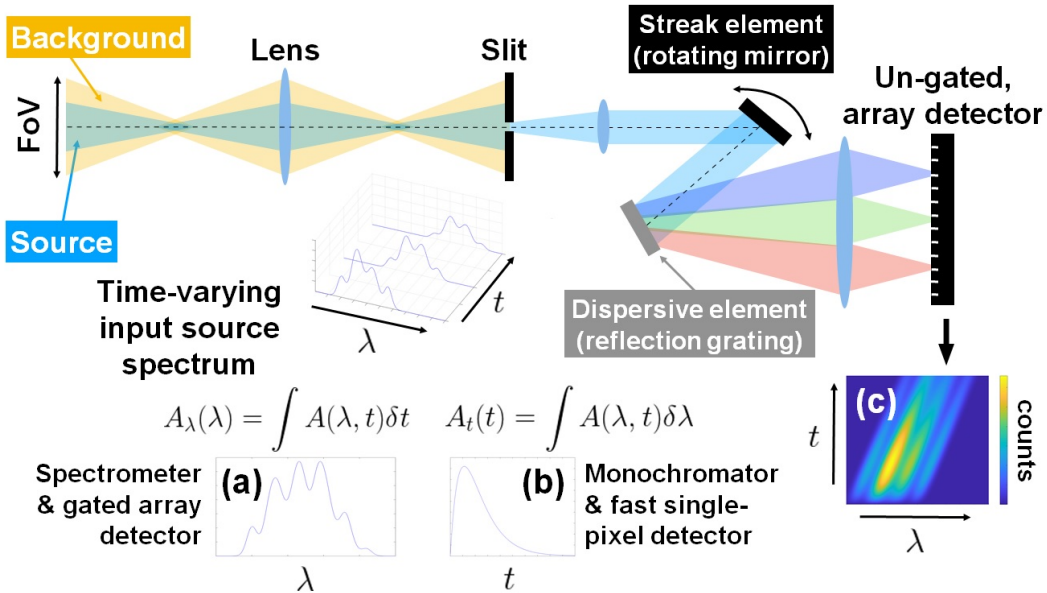


L. A. Finney et al., Opt. Lett., in press

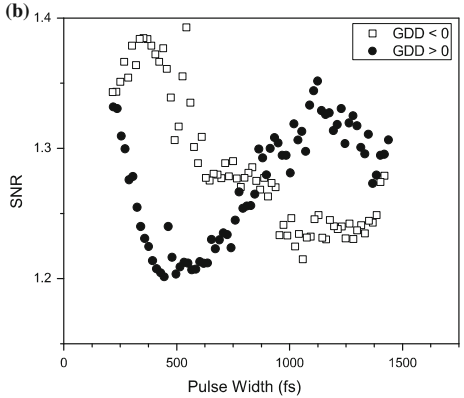


Multiple opportunities exist for enhancement of optical signatures

3D (λ_{ex}-λ_f-t) optical signatures

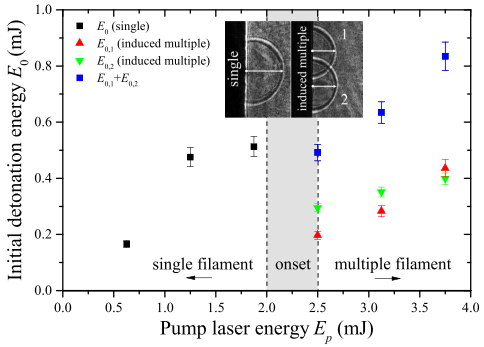


(Courtesy: P. Skrodzki)



Spectrally- and time-dependent excitation: coherent control

K. Hartig et al., JRNC 296, 135 (2013)

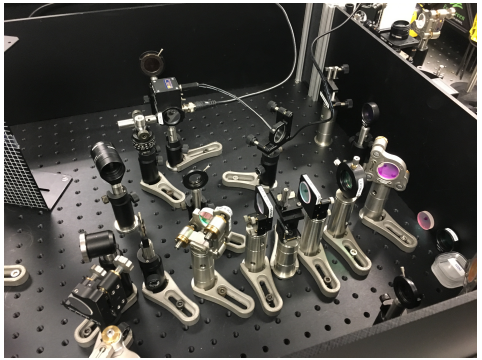


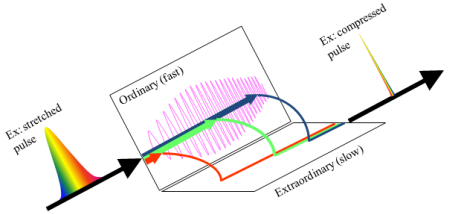
Control of beam intrensity and phase profile

P. Skrodzki et al, Sci. Rep. 7, 12740 (2017)

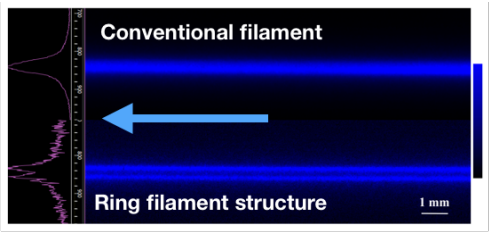
Technical Work Plan

- Generate novel and enhance existing optical signatures of proliferation-relevant elements, isotopes, and compounds
- Major tasks:
  - Develop a flexible source for tunable nanosecond pulsed excitation (optical parametric oscillator)
  - Implement and exercise the feedback loop for femtosecond pulse shaping





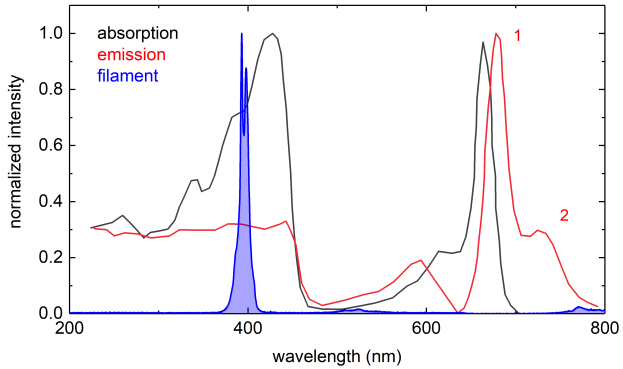
- Improve excitation and collection of optical signatures over extended distances
- Major tasks:
  - Push the detection into photon-number limited regime using electron-multiplying sensors
  - Use beams with high-order topological charge to improve coupling and guide optical emission by hydrodynamic shock guiding



Expected Impact

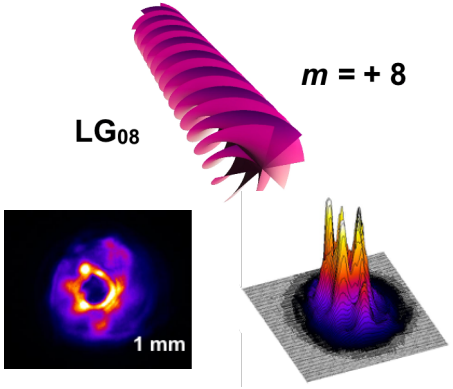
This work has a potential to impact several areas of science and technology relevant to detection of optical signatures from proliferation:

New signature generation and characterization



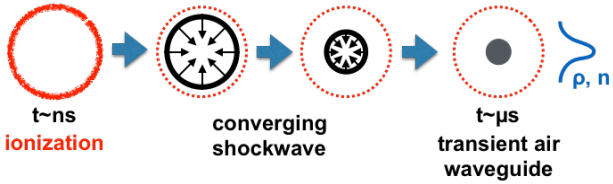
Chlorophyll (Courtesy: L. Finney)

Advanced optical sources and delivery



Vortex beams (Courtesy: M. Burger)

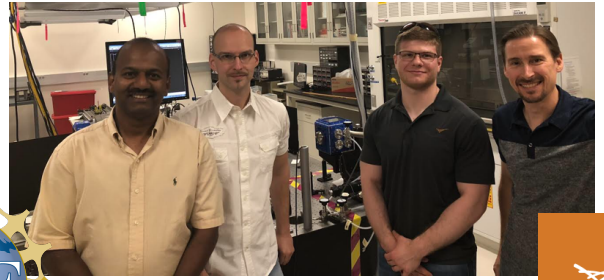
Collection and detection technology



Hydrodynamic shock guiding (Courtesy: P. Skrodzki)

MTV Impact

- Maintain the existing and establish new collaborations with national laboratories (PNNL, LLNL, LBNL)
- Fundamental contributions to signature science
- Outstanding opportunities for student scientific training
- Exceptional visibility and recognition of other funding agencies
- Support for participation in key technical meetings and workshops
- Student and postdoc transition into national laboratory and academic careers



Conclusion

- Optical signatures of proliferation-related elements, isotopes, and compounds are suitable for their detection and discrimination
- Spectral, temporal, and spatial characteristics of optical excitation sources and signatures can be harnessed to improve detectability
- This research aims to reduce detection time, reduce detectable limits, and increase standoff for detection of trace effluents and deposits , and enable in-field rapid chararacterization for nuclear forensics
- This research will leverage synergistic projects and relationships with national laboratories (PNNL, LLNL, LBNL) to promote technology and student transitions

Acknowledgements

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