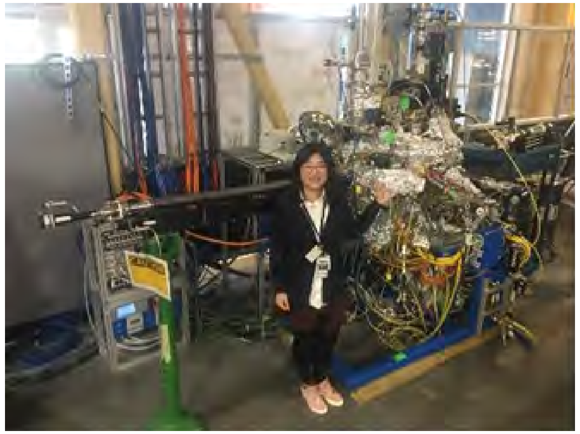
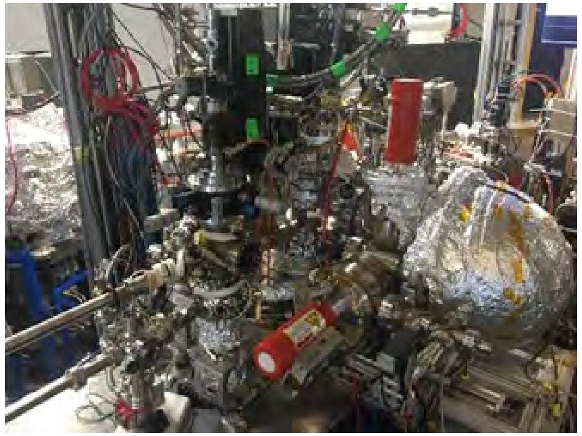
Yale MBE on the NSLS II floor

Develop molecular beam epitaxy (MBE) thin film deposition capabilities at the National Synchrotron Light Source II to fabricate synthetic quantum materials.





Yale MBE on the NSLS II floor at BNL

Yale-fabricated instrument requiring:

- *Machine shops to fabricate specialized parts, UHV welding.*
- *Materials characterization of grown materials: aberration corrected TEM, AFM, XRD.*
- *Software development for controls.*
- *Software training for students.*
- *Vacuum chamber pumping simulation.*

PI/Group

Charles Ahn and Fred Walker, Applied Physics

https://ahnlab.yale.edu/

Current Approach

PI design of chamber to achieve performance metrics, match NSLS II constraints on instrument footprint, and comply with BNL safety protocols.

Advanced Instrumentation Development Center needed for the following:

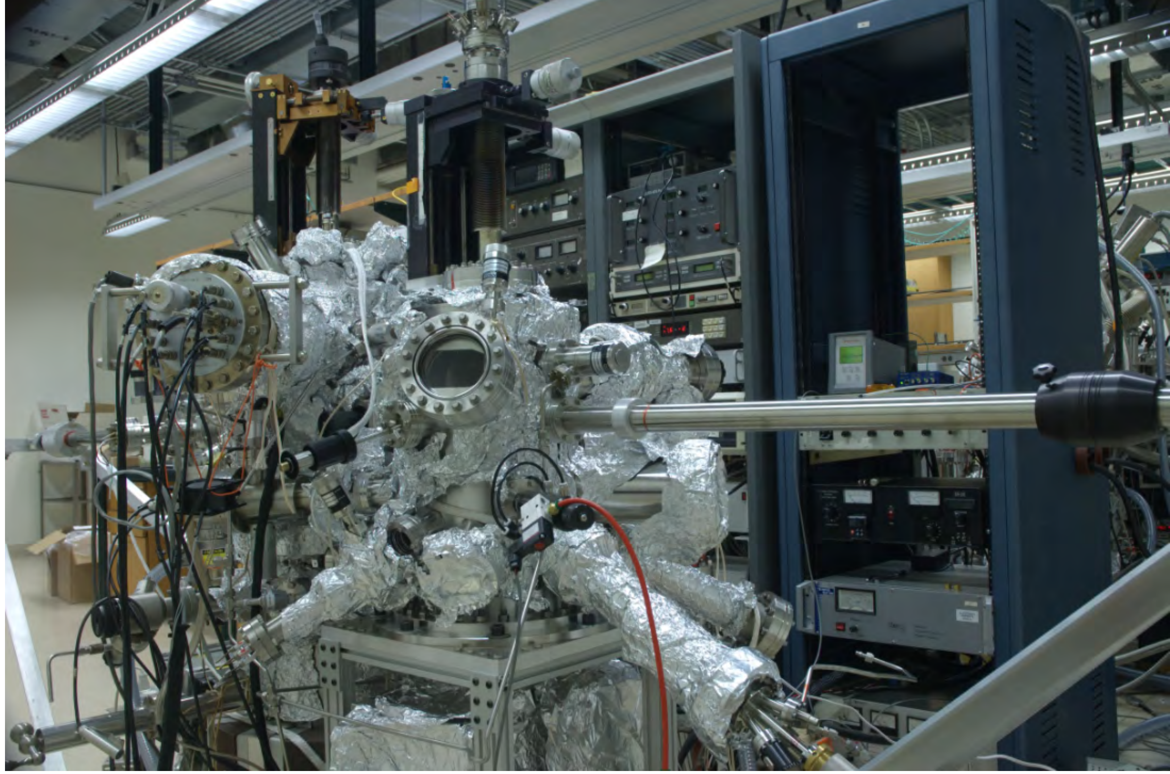
1) *Vacuum chamber design tools (software) and expertise (vacuum engineers).*
2) *Machine shop fabrication expertise to fabricate specialized parts for holding and manipulating samples, UHV welding expertise for making custom vacuum parts.*
3) *Training for students in the use of simulation programs such as COMSOL for vacuum chamber simulation.*
4) *Expertise in industrial laboratory safety to anticipate and address National Laboratory safety requirements.*
5) *Knowledgeable experts in computer control of instrumentation to develop custom control software and adapt commercial software to existing hardware.*

Project Goals

Advance and integrate multi-dimensional scanning probe microscopy for atomic-scale mapping of surface chemical interactions and for new materials development.

Resources Needed

Machine shop
Electronics shop
Software development
Tools for integration with machine learning/big data analysis



PI/Group

Eric Altman, Chemical & Env. Engr.
Udo Schwarz, Mech. Engr. & Mat. Sci.

Link/Reference

https://pubs.acs.org/doi/abs/10.1021/acs.accounts.5b00166

*E.I. Altman, M.Z. Baykara and U.D. Schwarz, Acc. Chem. Res. 2015, **48**, 2640.*

Current Use of Cores

Gibbs machine shop – fabricated scanning tunneling microscopes, customized UHV parts

Complementary measurements – x-ray diffraction, XPS, etc. YINQE, CRISP, West Campus Materials Core

How might a new instrumentation development center help?

Develop state-of-the art control electronics – higher speed, reliability and throughput.

Enable new imaging modes dependent on fast collection and storage of a large amount of data.

Integrate data collection and analysis – smart data collection and machine learning for chemical and property mapping of complex materials.

What difference can it make to your research and the training of personnel?

Research – create new opportunities to study complex materials and phenomena (e.g. quintenary alloys, 2D materials that couple magnetic, elastic and electrostatic responses.

Training – expand training opportunities to integrate the hot topics of big-data and machine learning.

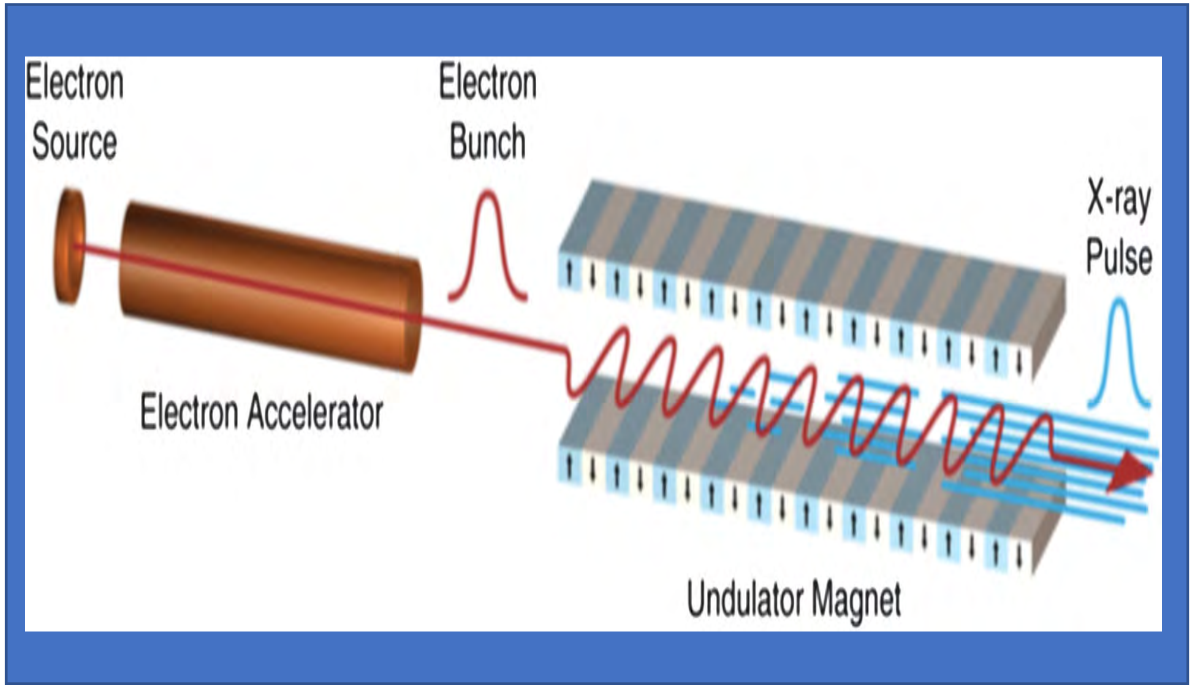
Project Goals

To build and operate a <u>transformative</u> compact free electron laser instrument for <u>innovative research</u> in the <u>physical, biological, and chemical sciences, along with medicine</u> on the Yale campus.

Resources Needed

- ***<u>Shops:</u>*** *Machine and Electronics Shops*
- ***<u>Expertise:</u>*** *Small accelerator operations*
- ***<u>Personnel:</u>*** *FEL operators, experiment shifters, hardware and software engineers, student and postdocs*
- ***<u>Management:</u>*** *Director, Budgeting, EH&S*

Largely already existing on campus!!



O.K. Baker*/Physics Department/Experimental Particle Physics at LHC and on campus*

https://hep.yale.edu/people/faculty/oliver-k-baker

Current Approach

Current on-campus resources are mostly in place for this project goals. Machine shops for professionals and properly trained students, electronics expertise, EH&S all exist in the Wright Lab. A re-orientation of the current Beam Physics Laboratory will be needed. Expertise in software development and use, as well as experimental setup and implementation exists in students and postdoctoral researchers. The FEL construction and its use will require trained personnel not all of whom are presently available at the University. The proposed approach is to partner with a major federal funding agency such as the Department of Energy in the FEL construction and operation.

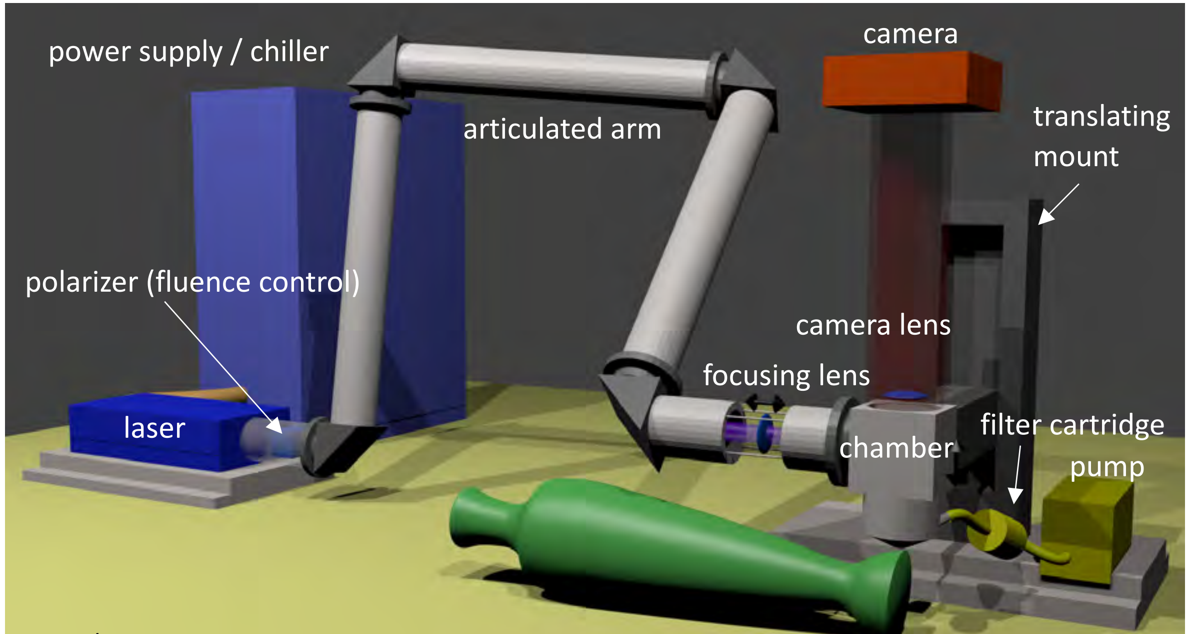
An instrumentation development center would enable urgent and fundamental innovative research in STEM and medicine in a campus environment where none exists at this level at universities. **University facilities allow quick and innovative results with an on-campus (IR) light source, and a stepping stone towards a future compact x-ray FEL.**
Examples include: FEL use in understanding COVID-19 at a fundamental microscopic level. Twisted beams of electrons and photons for quantum information science R&D. Search for Beyond the standard model phenomena in experimental particle physics. It provides a great training venue for students and postdoctoral researchers.

Project Goals

Build and commission a rugged and **portable ultraviolet (213 nm) laser ablation micro-sampling device** to enable in situ sample removal from cultural heritage objects and natural history specimens comprising transparent and translucent materials prone to brittle fracture. The ablated material is deposited onto pre-cleaned filters, which are later processed for elemental and isotope analysis using ICP-MS and/or TIMS. Equip 2nd generation design with gate-delayed spectrometer to allow **tandem Laser Induced Breakdown Spectroscopy (LIBS) and laser ablation**. The portable sampling tool will be used in Yale's museums and collections, by Yale researchers for field work, and will serve as a model for use by other cultural heritage institutions.

Resources Needed

- *Advanced Prototyping Center, Machine Shop, Electronics Shop*
- *Yale Metal Geochemistry Center & Cleanroom (G&G/E&PS)*
- *Expertise: optics & pulsed lasers; ICP-MS & TIMS; cleanroom; sample digestion & preparation; LIBS; engineering; data science*
- *Training: laser safety, clean room use, instrumentation use, museum object handling, optical spectroscopy*
- *Personnel: research scientists @ Cores, machine shop, engineers, postdocs*
- *Management: budget/expense tracking, postdoc recruitment & supervision*



Image/design: Pablo Londero

PI/Group

Anikó Bezur, Technical Studies Lab, Institute for the Preservation of Cultural Heritage

Link/Reference: Based on visible 532 nm laser ablation device.

Current Approach

Prototype 1

- Ablation chamber: Advanced Prototyping Center
- Laser support: Gibbs Machine Shop
- Filter cleaning, sample digestion, elemental and isotope analysis: Yale Metal Geochemistry Center & Cleanroom

How might a new instrumentation development center help?

What research would be enabled by an instrumentation development center?

- A portable UV laser ablation micro-sampling device will enable trace element and isotope analysis of a whole class of cultural heritage objects that has been off-limits to any analysis other completely non-destructive approaches, such as x-ray fluorescence and Raman spectroscopies. This opens the door to addressing questions about materials sources, material processing technologies, and degradation mechanisms. Whole or reassembled objects made of brittle and transparent/translucent materials are rarely sampled, because mechanical sample cause micro-cracks that lead failure. A portable ultraviolet laser ablation device will permit safe and virtually unnoticeable sampling that can be conducted in the object's collection environment, further reducing risk from transportation.
- The addition of LIBS capacity to the sampling device will allow instant elemental analysis capacity and results that will complement later sample workup with ICP-MS and TIMS.

What difference can it make to your research and the training of personnel?

- It can lower the activation barrier for the customization of existing instrumentation or the creation of new solutions for cultural heritage objects and environments.
- Provide integrated and more efficient onboarding of students, postdocs, and research staff with respect to resources at Yale.
- Serve as a networking point and a springboard for professional development through training, courses, seminars, and events.

Project Goal:

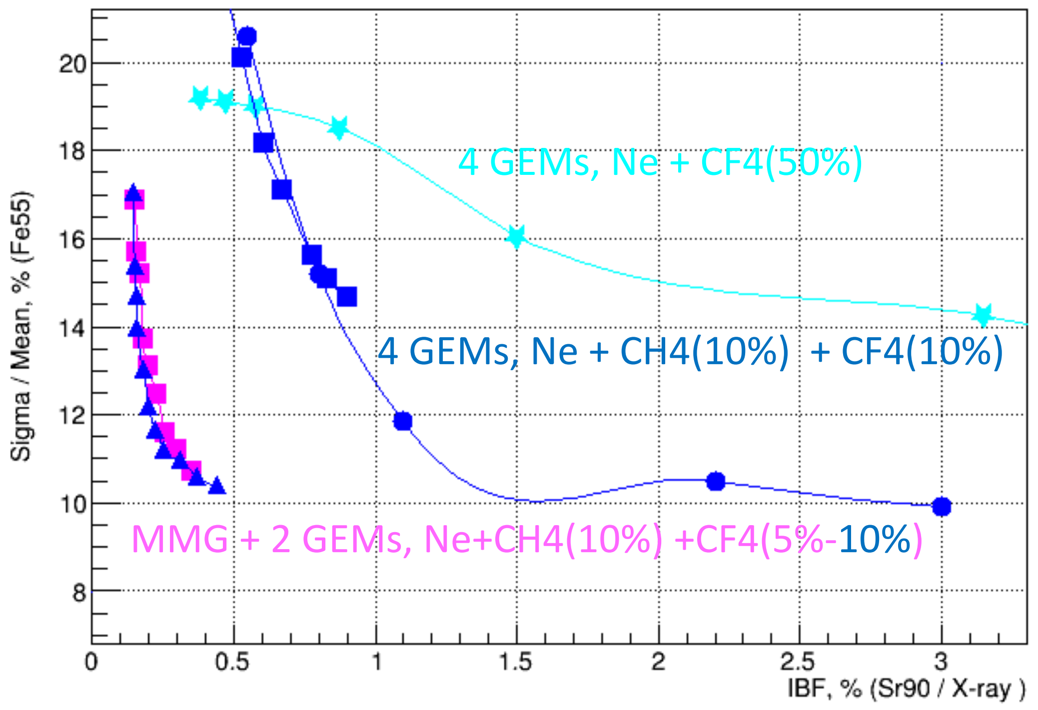
<u>Options for Gain Elements for High Rate Time Projection Chambers</u>

MPGD for Tracking and PiD.

Study and select optimal Gas Mixtures.

R&D, Prototypes, Mass Production, Test, Calibration, Certification, and Utilization.

Relativistic Heavy Ion Group, Wright Lab, Physics Department, Yale University.



Resources Needed:

Machine Shop & Student Machine Shop
ITS software library & Computing support
Mechanical Engineers and Technician support
Electronics Shop and Engineers

Project Leader:

Dr. Nikolai Smirnov
(Caines-Harris Group)

Current Status:

We have two Laboratories and a “Clean Room” in “active” use.

-- Supporting the ALICE Time Projection Chamber (TPC) team at the CERN Large Hadron Collider as a stand-alone and the only available R&D and test laboratory in ALICE during installation and commissioning of the TPC readout chambers.

Future Prospects:

-- Continue investigations of a possible high-rate TPC option, its gain elements and gas mixtures for the STAR experiment at Brookhaven Laboratory, the future sPHENIX experiment at Brookhaven, and for future detectors at the Electron Ion Collider (EIC) and Linear Collider.

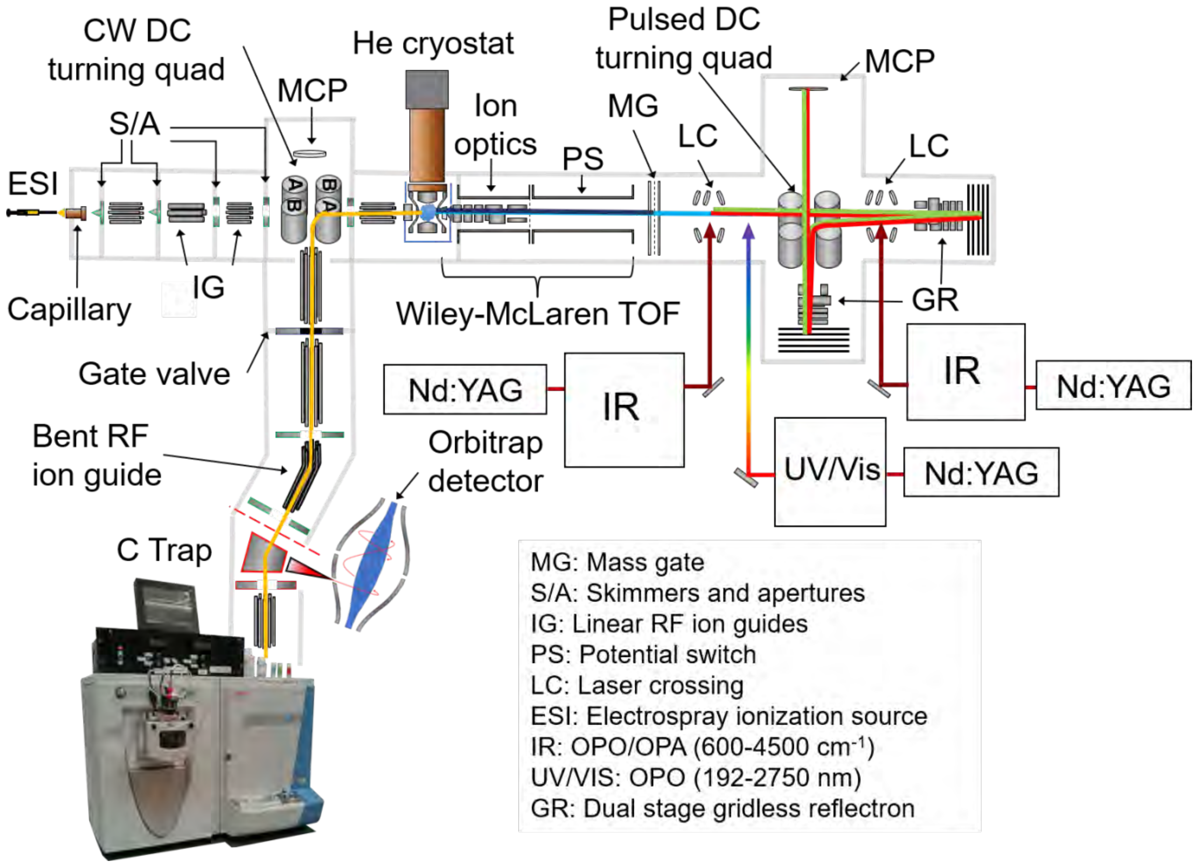
-- Currently presenting reports and presentations on the progress and developments to these various groups/experiments.

-- Continue developing designs and operational parameters for construction of new detectors for the EIC expected to come online in 2030. This is a critical issue for the ongoing preparation of the technical design report for detector systems for the EIC.

Project Goals

Build and commission a **hybrid mass spectrometry/optical spectroscopy instrument** for chemical analysis. This is to be housed in the Chemistry and Biology Instrument Center and managed by a staff member (Dr. Fabian Menges) for **general use by the chemical and biological sciences** at Yale.
The instrument uses class IV lasers and can therefore not be operated as a walk-up instrument (safety concerns and experience needed).

*The **instrument and the control software** need to be designed so that a **minimum amount of operator time** is needed, otherwise it won't be used!*



https://link.springer.com/article/10.1007/s13361-019-02238-y

Resources Needed

Machine Shop & Student Machine Shop
ITS software library (licenses for e.g. Autodesk Inventor)
Facilities
Budget tracking
Programming Classes
Electronics Shop and Engineers
Mechanical Engineers for optimization of design

PI/Group

Mark Johnson

Current use of Cores, needed personal development (amplified by training resources) and potential advances through an 'Advanced Instrumentation Development Center'

Mechanical Parts:

- Autodesk Inventor student license through ITS software library - software training
- Revision of design by engineer
- Student workshop for basic metal manufacturing techniques
- Machine shop for manufacturing of parts
- vacuum grade welding in the machine shop
- integrated workflow from CAD design to CNC machine manufacturing

Control Electronics:

- electronics specialists in the fields of:
    - microcontrollers
    - instrument communication & interface design
    - circuit design for DC power supplies, remote control of these and TTL triggering
    - Radio Frequency applications
- cryo engineer for optimization of the existing design with respect to heat transfer, would also be great for having a look at the CBIC Helium recovery system, cryo EM facilities, our lab and likely for several others
- engineer in material flow simulation who could help optimize He buffer gas cooling, optimizing vacuum envelopes with respect to leak rates, pumping efficiency etc.

Control Software:

- ITS software library - software training classes
- Software engineer to discuss the scope of the project and guidance on program design - programming as part of the instrument development
- Outsourcing of tasks that are too complex for a beginner/intermediate in programming

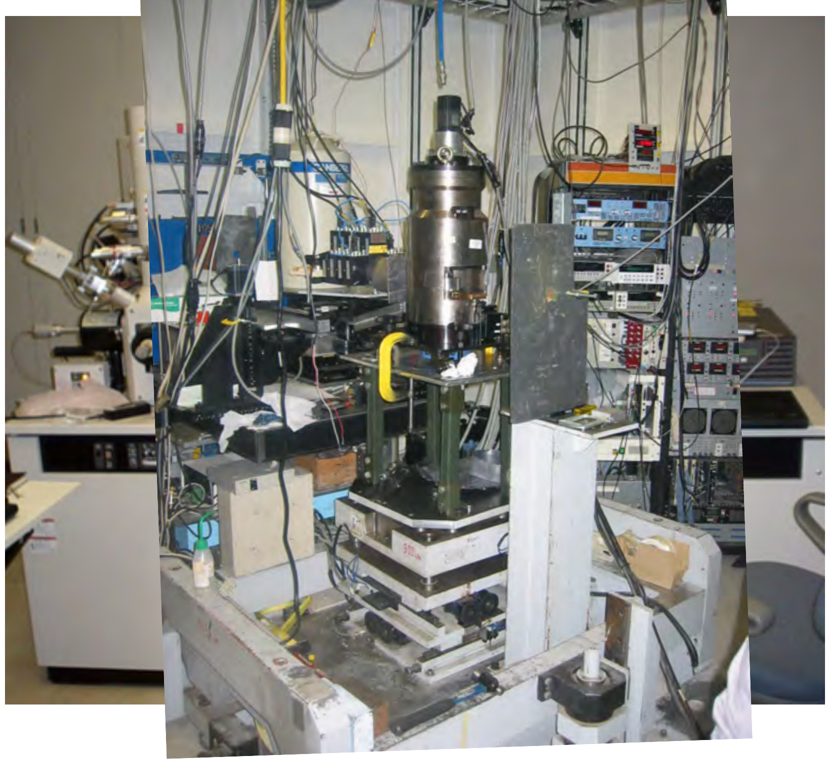
Project Goals

Understanding the composition and evolution of Earth and other planets from the properties of rocks

Resources Needed

List your needed resources such as

- *Shops: electronics shop*
- *Cores: TEM,FIB*
- *Expertise: operation of TEM, FIB*
- *Training: training of users, workshops to do hands-on training of new methods*
- *Personnel: dedicated specialists with expertise in TEM, FIB operation*
- *Management: Financial support from Yale is essential to reduce the users' fee (to cover a part of maintenance cost).*



PI/Group

Shun-ichiro Karato

Mineral and rock physics

Department of Earth and Planetary Sciences

Link/Reference

https://people.earth.yale.edu/profile/shun-ichiro-karato/about

Current Approach

We conduct experimental studies using (i) our own facilities in our lab and (ii) nation-wide facilities such as synchrotron facilities (Brookhaven, Argonne). Activities using (ii) are supported by a consortium. In addition, we need university-wide facilities (such as TEM, FIB) to analyze samples. These facilities at Yale are very limited in comparison to those in other world-class institutions and we cannot do these activities at Yale. At the moment, we rely on collaborations with other scientists at other institutions (mostly in other countries).

How might a new instrumentation development center help?
What research would be enabled by an instrumentation development center?
What difference can it make to your research and the training of personnel?

With facilities on campus, we can investigate samples ins and outs. This is hard when we need to send samples out.
Installation of FIB and TEM with dedicated technical personnel will be essential.

Sensing the Environment

Environmental systems are very complex with a large amount of spatial and temporal variability. One cutting edge is the development of **new sensor technology**. We believe there is an opportunity to **connect current infrastructure across Yale and build out some new infrastructure to both seize on new initiatives around sensor technology and make sensor technology development more accessible to folks across the University**.

Included in this effort would be:

- Developing new sensors
- Deployment of sensors in harsh environmental environments
- Deployment of network sensors (internet of things)
- Communicating, analyzing and presenting large environmental sensor data sets

There is a huge amount of **intellectual capacity** here at Yale around the environment/ecology (some already using sensors and pushing sensor technology). There are also strengths and physical capital with respect to **fabrication facilities**.

What we need are some **improvements in physical capital (e.g., electronics)** but also research/data/coding environmental **research engineers** dedicated to connecting the intellectual capacity around environment/ecology with next generation approaches for sensing the environment in order to answer cutting edge questions around the environment.

We see an effort on "Sensing the Environment" as a great opportunity to bring together scholars across campus and in direct alliance with the Planetary Solutions effort developed from the USSC report.

PI/Group: Peter Raymond (FES), David Bercovici (G&G), Walter Jetz (EEB), Aaron Dollar (YSEAS), Karen Seto (FES), Noah Plavansky (G&G), Drew Gentner (YSEAS), David Skelly (FES), Indy Burke (FES)

Project Goals

Development of a user facility for mechanical and thermal measurements

Yale is a top tier research institution but surprisingly without any user mechanical and thermal analysis characterization facilities.

Main issues –

- Lack of up to date equipment – current mechanical testing equipment available in teaching labs only (which cannot be used for research) is basic with most equipment being >10 years old.
- No dedicated staff to take care of the equipment, which causes equipment to break down frequently.
- Paltry resources compared to other most of our peers (and even most state schools).

Resources Needed

Characterization Equipment.

Dedicated and capable research support staff.

Thermal Analysis

DSC TGA DMA TMA Laserflash

Mechanical Analysis

Uniaxial/Biaxial/Shear Testers Nanomechanics

PI/Group

Dr. U.D. Schwarz

Dr. J. Schroers

Dr. A. Datye

Link/Reference

https://www.ccmr.cornell.edu/facilities/instruments/

https://www.ims.uconn.edu/facilites/#

http://jiam.utk.edu/laboratories.php

Current Approach

Since there is no user facility to study mechanical and thermal properties, most faculty have to pay user fees to other institutions or write proposals for user facilities at national laboratories, which takes time away from the actual research (including travel times) along with limiting the experiments that can be performed.

How might a new mechanical and thermal instrument center help?

Currently: Ancient equipment with no support => Consolidating and upgrading equipment –
Most of current equipment at Yale is ancient and must be upgraded to the latest standard at the earliest. There are various pieces of equipment at Yale with different departments that have either been left over from faculty leaving or purchased by the department for teaching purposes. The common thread in all of these is that they are left without proper care and maintenance and consequently are often inoperable.

1. The differential scanning calorimeter (DSC) in MEMS, which is frequently used by students from five different research groups is approx. 15 years old. The manufacturer (TA instruments) will stop supporting that version of the product next year, which means when it breaks (which is inevitable), it cannot be repaired anymore, leaving many students without access to vital instrumentation.
2. The chemical engineering department has the same DSC (left by a leaving faculty). However, unlike in the MEMS Department where the Department constantly orders a person to repair and recalibrate the instrument, ChemE appears to lack that ability. As a consequence, the equipment is currently broken.

What research would be enabled by an instrumentation development center?

This proposed user facility would support a wide user base of Yale faculty who need mechanical and thermal properties measurements.
Example: A nanomechanical tester needed by at least six Yale faculty in different schools (Medicine, Engineering & Applied Sciences, FAS) and six different departments to successfully complete currently federally funded research is urgently needed (have currently to use outside user labs).

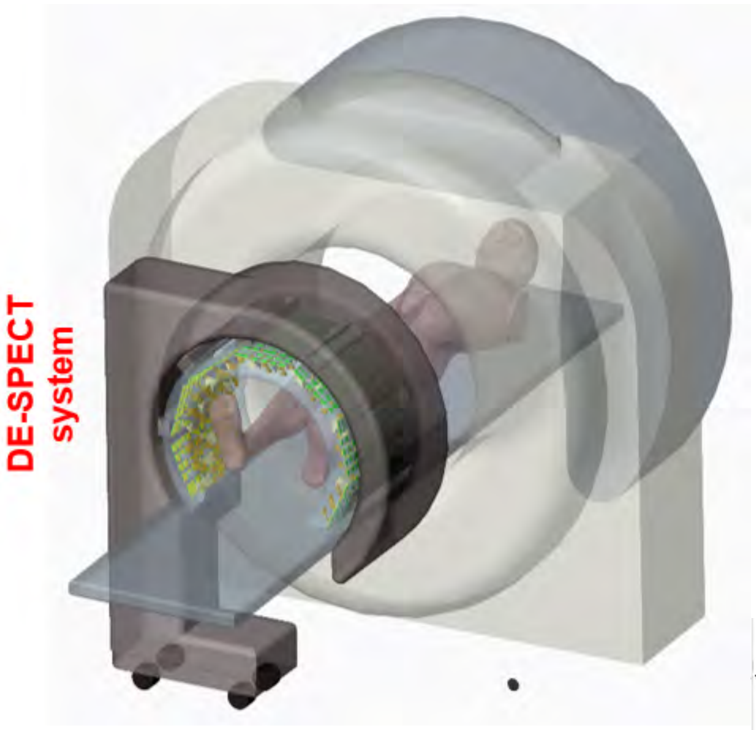
What difference can it make to your research and the training of personnel?

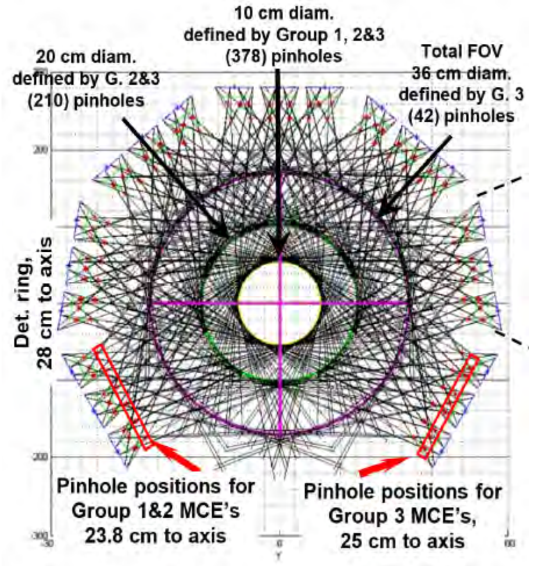
Besides supporting a variety of currently federally funded research at Yale, this facility will train Yale undergraduate and graduate students in the use of advanced equipment and expose them to the cutting edge of science.

Project Goals

There is a critical need for a non-invasive imaging approach for the comprehensive assessment of molecular and physiological changes of the lower extremities in patients with peripheral vascular disease (PVD) in response to therapeutics.

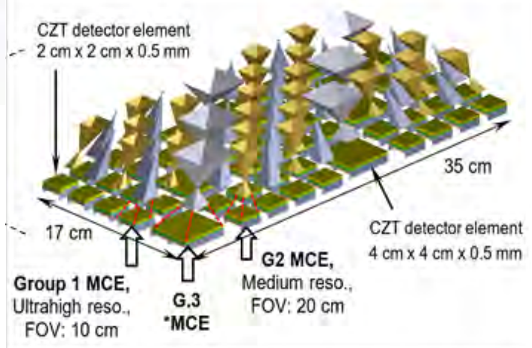
We propose to develop a portable reconfigurable Dynamic Extremity SPECT (DE-SPECT) system that utilizes the 3-D HEXIETC CZT detector technology and a synthetic compound-eye (SCE) camera design for dynamic and multi-tracer SPECT imaging in PVD.





Resources Needed

- Machine shop for fabrication of phantoms
- Electronics Shop and Engineers
- Mechanical Engineers for optimization of design
- Access to advanced computing and high speed network
- Phantom and preclinical testing and validation of system to be performed in the Yale Translational Research Imaging Center



PI/Group

Albert J. Sinusas, MD (Yale)

Yale Translational Research Imaging Center (Y-TRIC)

Chi Liu, PhD (Yale)

Ling-Jian Meng, PhD (University of Illinois)

Scott Metzler, PhD (University of Pennsylvania)

https://medicine.yale.edu/intmed/cardio/ytric/

Current Approach

This is a collaborative project between Faculty at the Yale University School of Medicine and engineers at Beckman Institute of the University of Illinois at Urbana-Champaign and at the University of Pennsylvania that is funded by a multi-PI NIH R01 grant.

Dr. Ling-Jian Meng (PI) from UIUC will be leading the hardware development efforts. **Dr. Scott Metzler (Co-PI)** from UPenn will be working on Monte Carlo modeling for optimizing the design of the DE-SPECT system and developing dedicated image reconstruction techniques. **Dr. Chi Liu (Co-PI),** from the Yale will focus on tracer kinetic modeling approaches for dynamic SPECT imaging, and **Dr. Albert Sinusas (Co-PI)**, Director of Y-TRIC and Clinical Advanced Cardiovascular Imaging at Yale, will perform phantom, preclinical and clinical evaluation of the DE-SPECT system. **Dr. Matt Wilson** external consult will advise on the development of the HEXITEC ASIC. Redlen Technology of Canada will serve as a commercial partner to refine the design and fabrication process of the CZT detectors

Mechanical Parts:

- Mechanism to adjust height of imaging gantry and move detector modules to expand axial field of view

Control Electronics:

Electronic specialists in field of:

- Instrument communication and interface design
- Circuit design

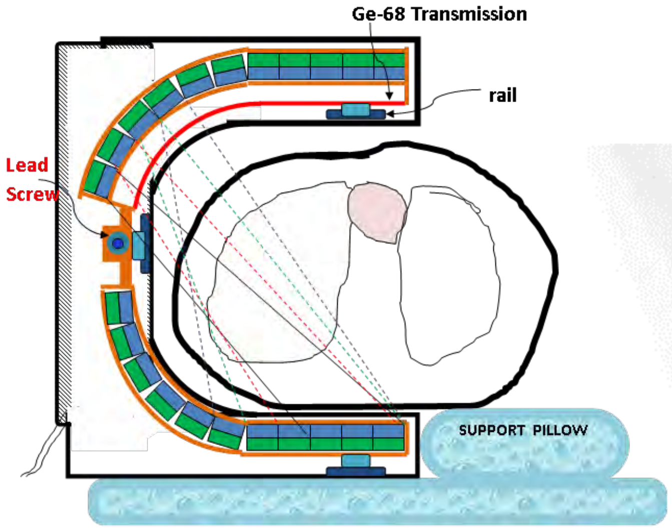
Control Software:

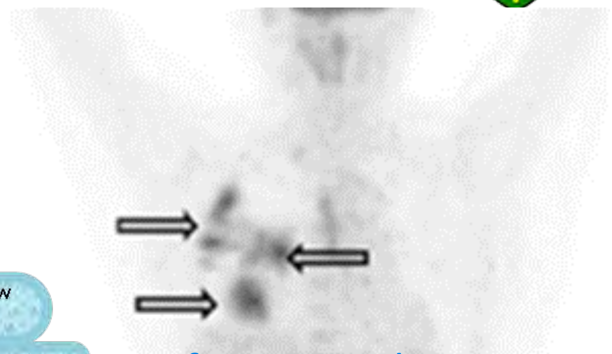
- Software engineer for control design and interface with commercial SPECT scanner and rotate gantry

LMI: Lung Molecular Imager

Project Goals

There is a critical need for rapid evaluation and risk stratification of patients with COVID-19 that require care in the intensive care unit (ICU), many of which end up on ventilators with complicating acuter respiratory distress syndrome (ARDS) mediated by inflammation. Transporting highly Infectious Patient from ICU to Radiology is Almost Impossible. **We propose to develop a portable PET scanner for molecular imaging of lungs in the ICU.**




Infection in the Lung

Resources Needed

- Machine shop for fabrication of phantoms
- Mechanical Engineers for optimization of design
- Phantom and preclinical testing and validation of system to be performed in the Yale Translational Research Imaging Center

PI/Group

Albert J. Sinusas, MD (Yale)

Yale Translational Research Imaging Center (Y-TRIC)

Farhad Daghighian, PhD (Prescient Imaging)

http://prescient-imaging.com/

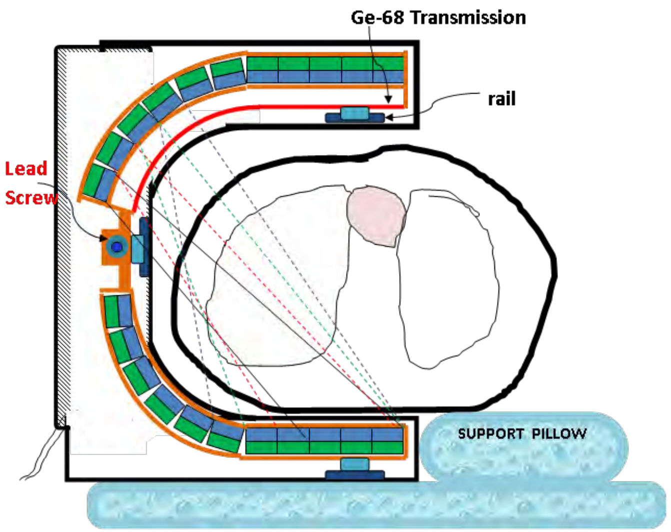
LMI: Lung Molecular Imager

Portable PET Scanner for Imaging COVID-19 Patients in ICU

Current Approach

This is a collaborative project between Faculty at the Yale University School of Medicine and engineers at Prescient Imaging a start up company located in Southern California, with support of medical physicist at the University of Pennsylvania.

Dr. Farhad Daghighian of Prescient Imaging will be leading the hardware development efforts. **Dr. Albert Sinusas**, Director of Y-TRIC and Clinical Advanced Cardiovascular Imaging at Yale, will perform phantom, preclinical and clinical evaluation of the lung molecular imaging (LMI) system. **Dr. Joel Karp** of University of Pennsylvania will serve as a consult for development of reconstruction algorithms and time-of-flight reconstructions.



Mechanical Engineering:

- Need mechanical engineering support for design of cart and movement of detector gantry.