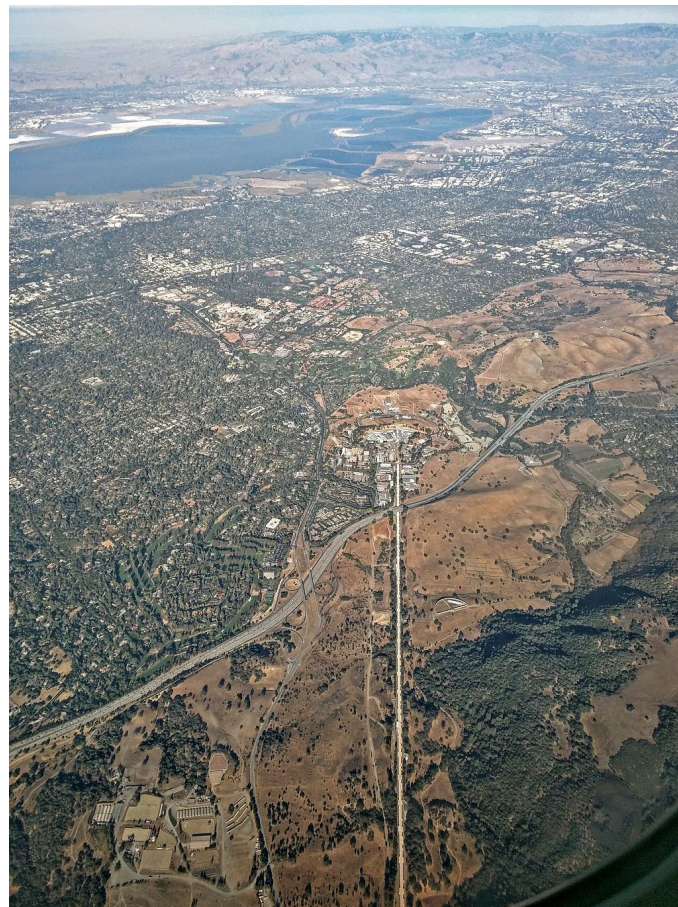


# The UH FEL and what will happen next?

Siqi Li  
Colloquium 9/26/2024



Fermilab  
Lee Teng internship



SLAC

# The Linac Coherent Light Source (LCLS) at SLAC





## John M.J. Madey Inventor of the FEL

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 17, 074901 (2014)

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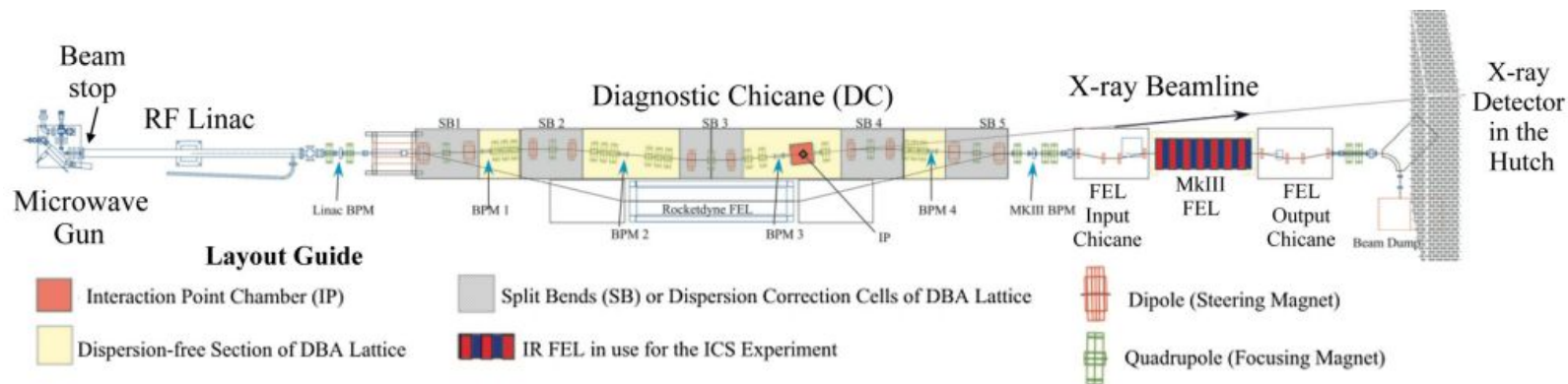
### Wilson Prize article: From vacuum tubes to lasers and back again<sup>1</sup>

John M. J. Madey\*

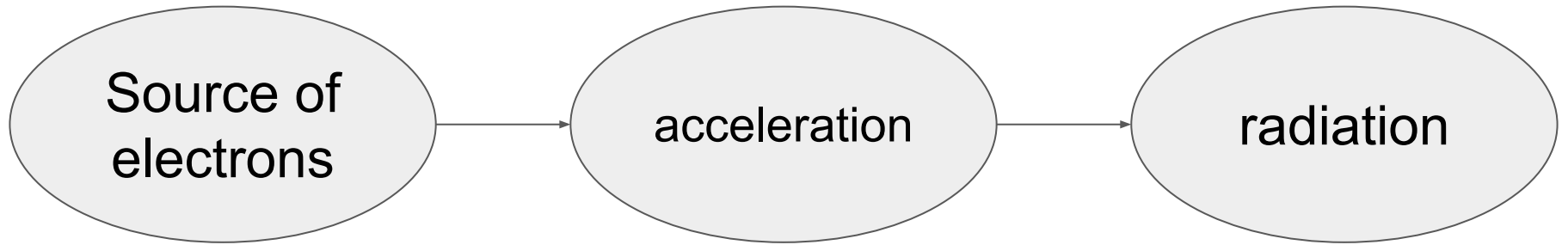
*Department of Physics and Astronomy, University of Hawai'i at Manoa, Honolulu, Hawaii 96822, USA*  
(Received 5 May 2014; published 16 July 2014)

The first demonstration of an optical-wavelength laser by Theodore Maiman in 1960 had a transformational impact on the paths that would be blazed to advance the state of the art of short wavelength coherent electron beam-based radiation sources. Free electron lasers (FELs) emerged from these efforts as the electron beam-based realization of the pioneering model of atom-based “optical masers” by Schawlow and Townes, but with far greater potential for tunable operation at high power and very short wavelengths. Further opportunities for yet greater capabilities may be inherent in our still growing understanding of the underlying physics. This article focuses on the FEL efforts in which the author was directly and personally involved.

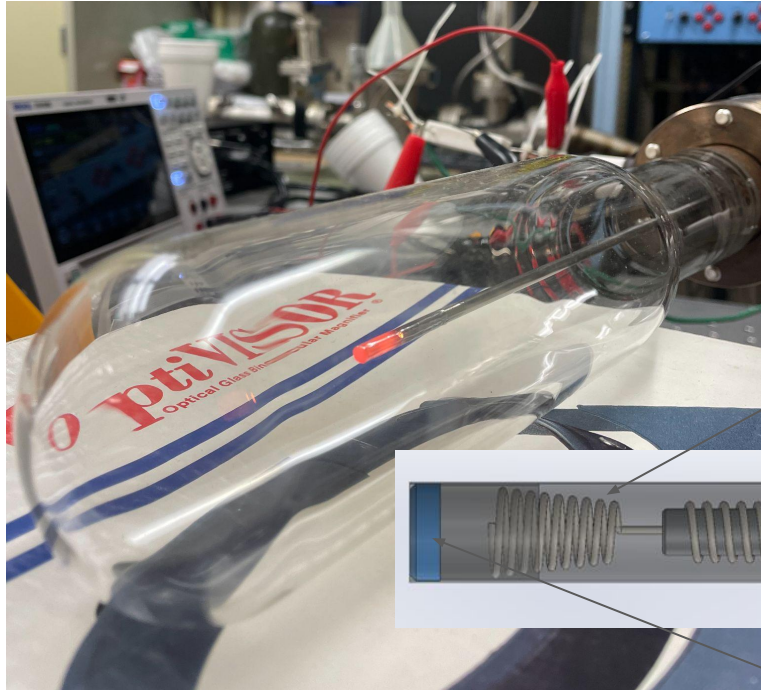
# The UH FEL



# Free-electron laser



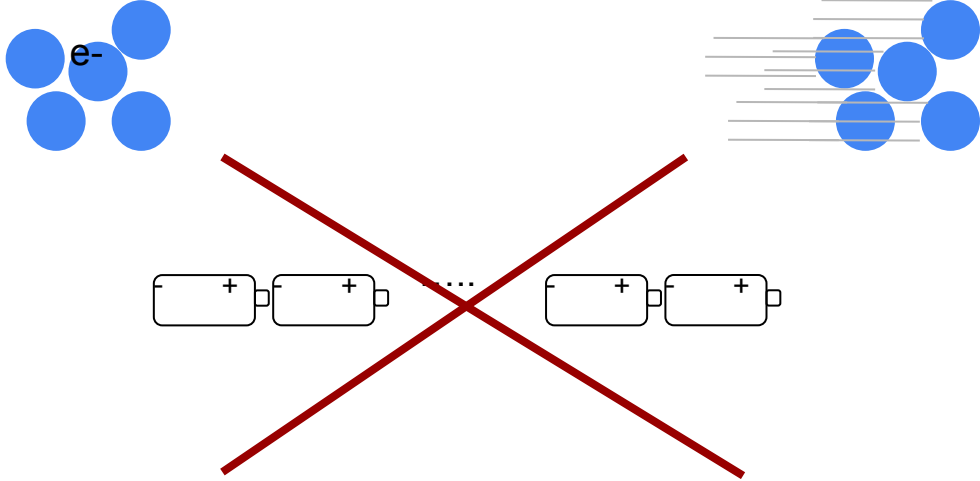
Source of electrons



Heater coil

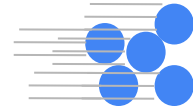
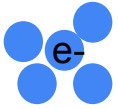
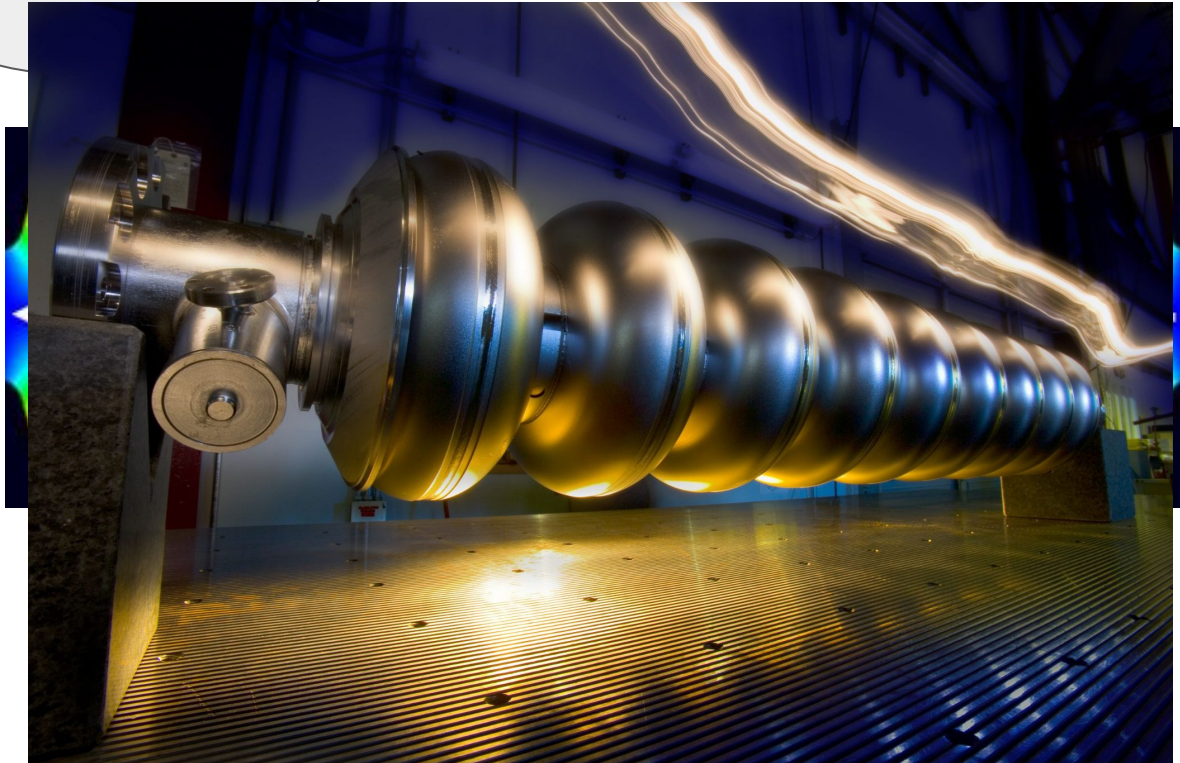
LaB6 cathode ( $\sim 1800$  K)

acceleration

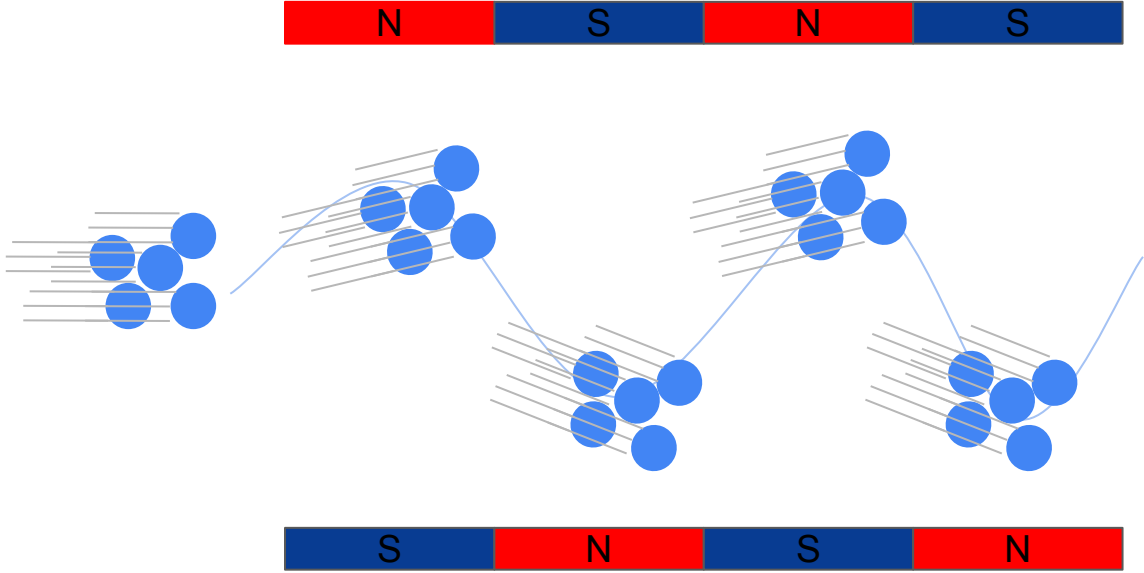


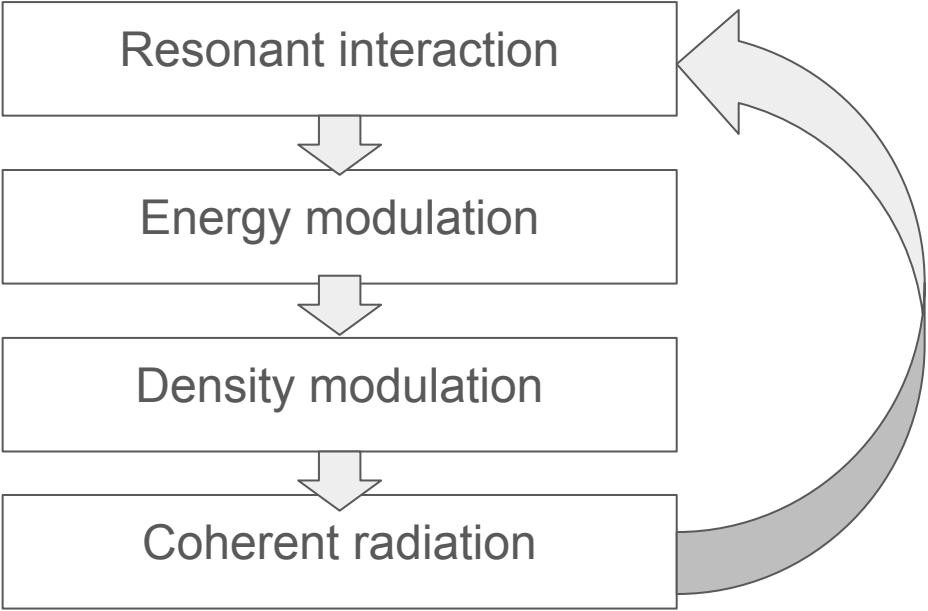
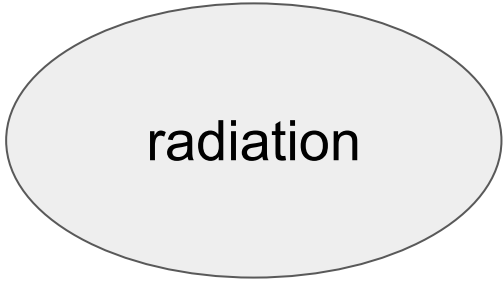


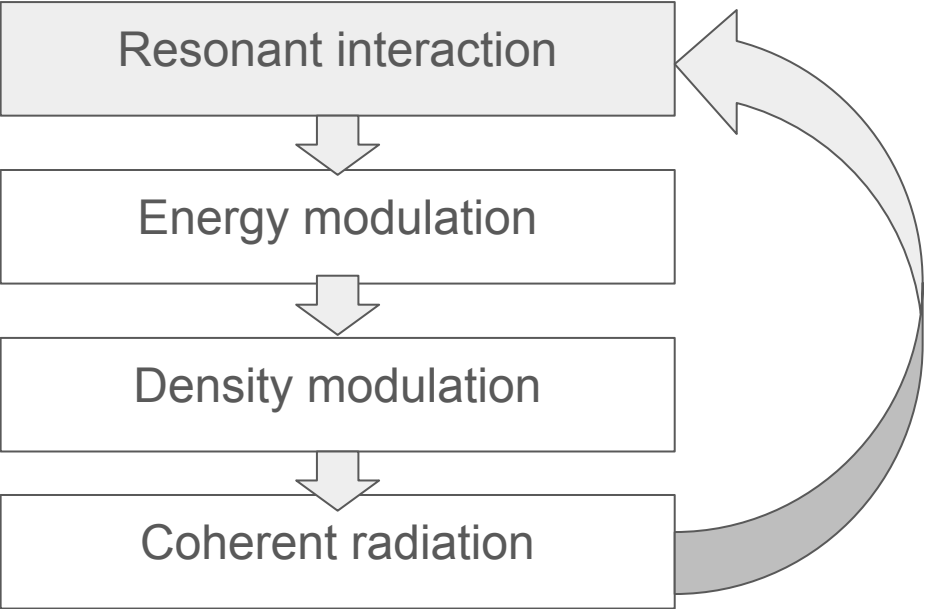
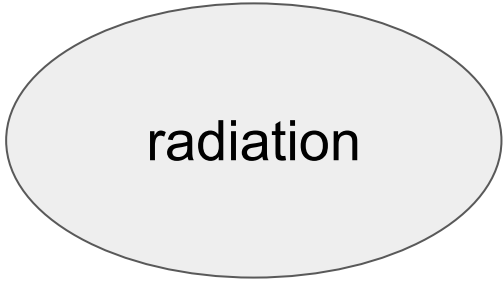
acceleration



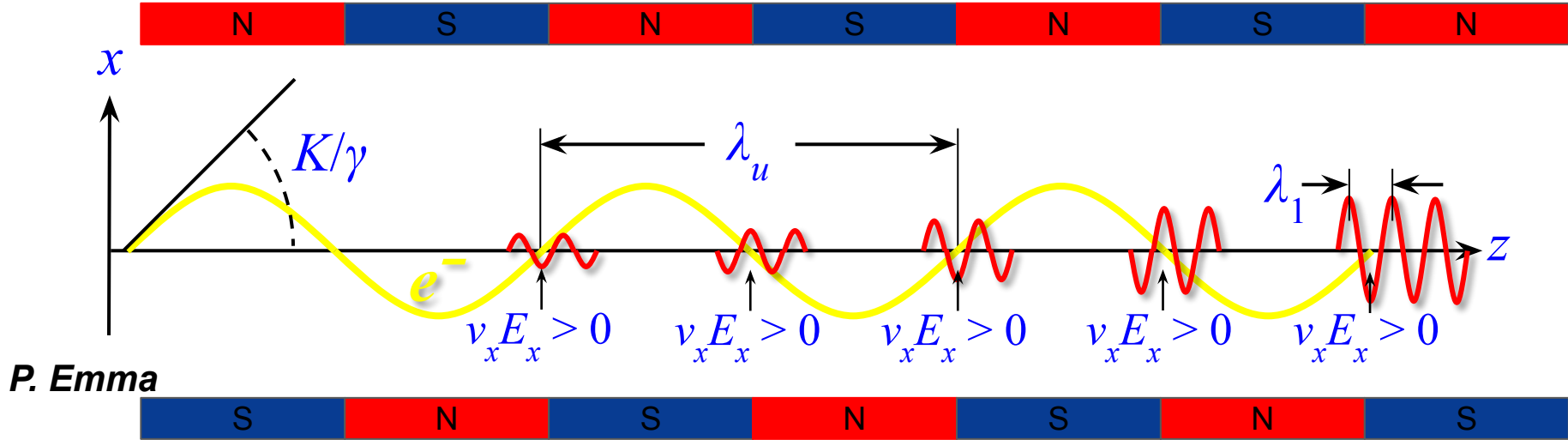
radiation







# Resonant interaction



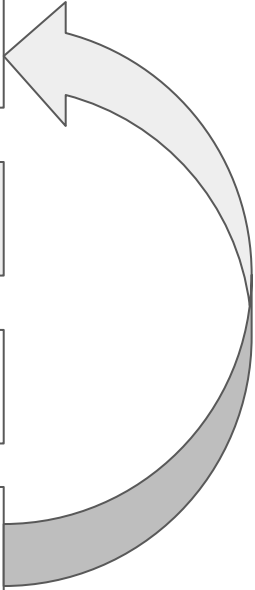
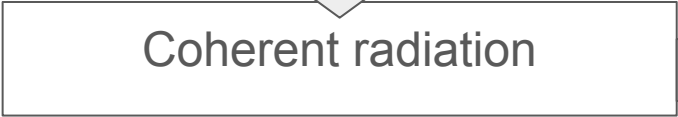
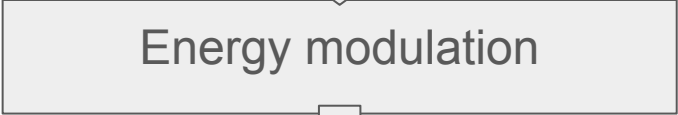
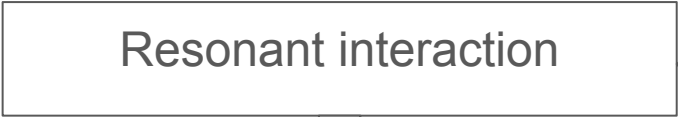
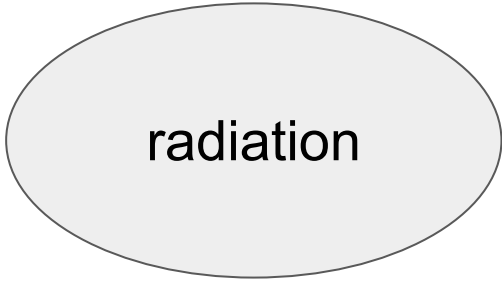
P. Emma

$$\lambda_1 = \frac{\lambda_u}{2\gamma^2} \left( 1 + \frac{K^2}{2} \right)$$

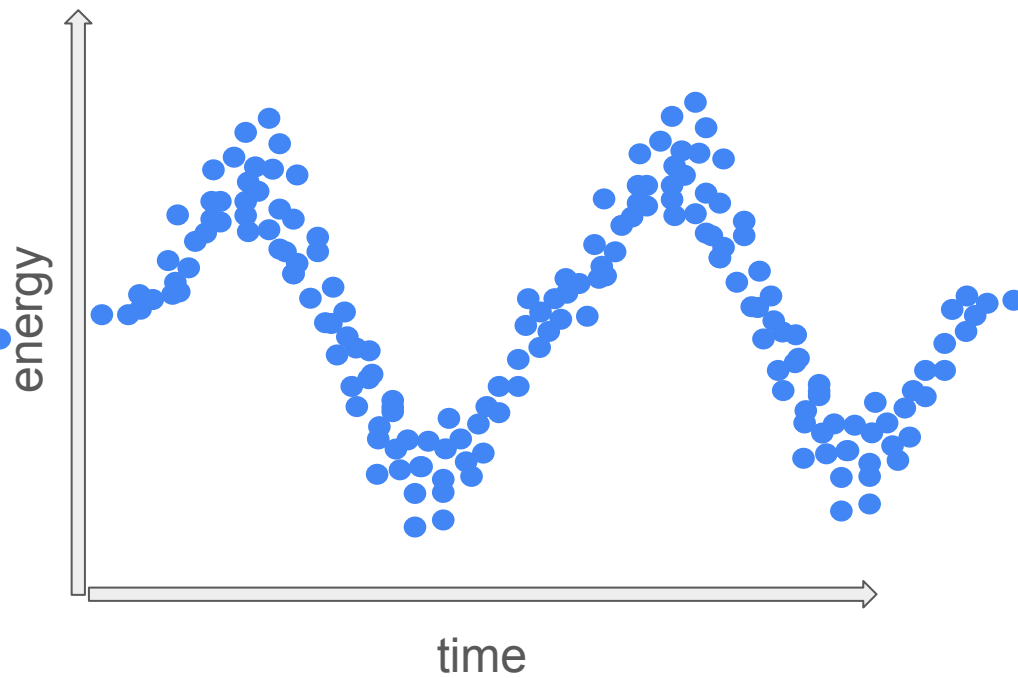
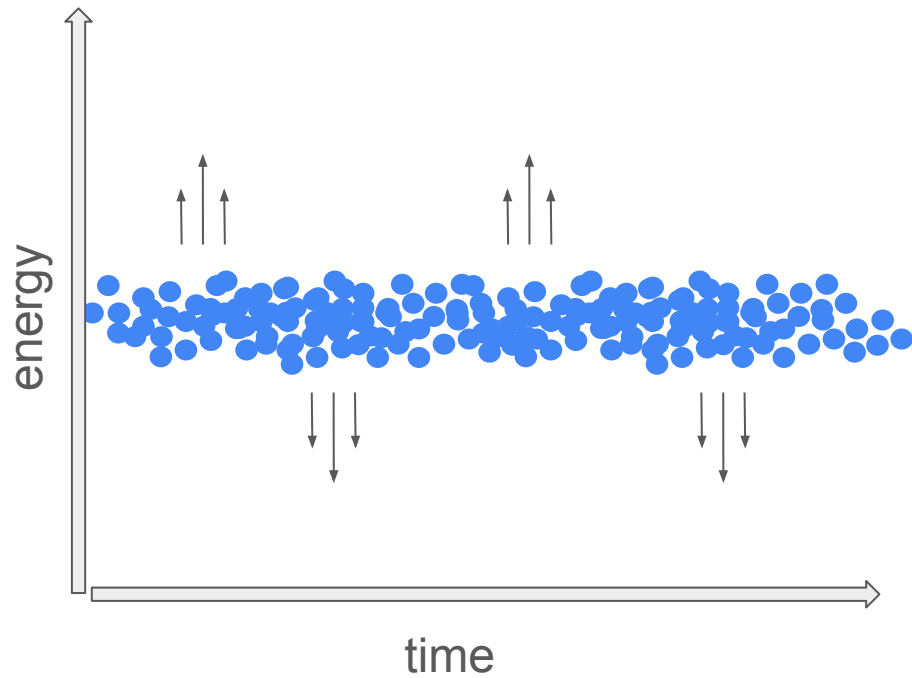
## Resonant interaction

$$\lambda_1 = \frac{\lambda_u}{2\gamma^2} \left( 1 + \frac{K^2}{2} \right)$$

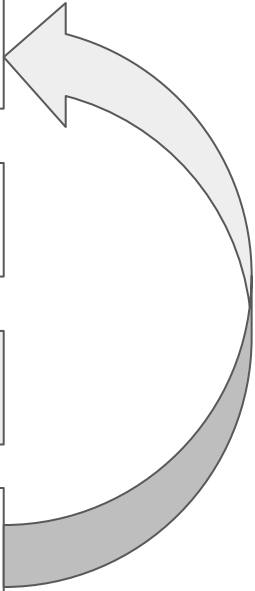
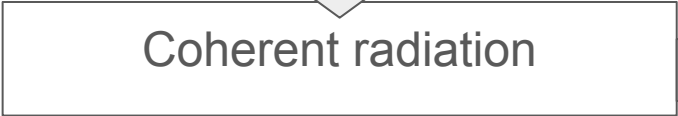
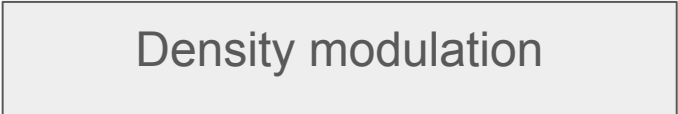
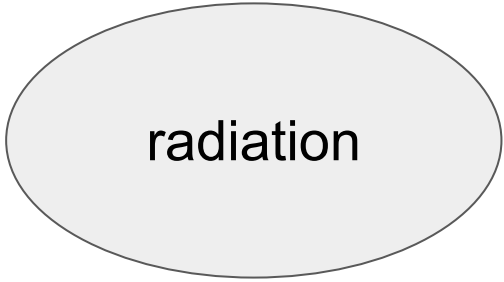
Radiation slips ahead of the e- by  $\lambda_1$  per  $\lambda_u$ .



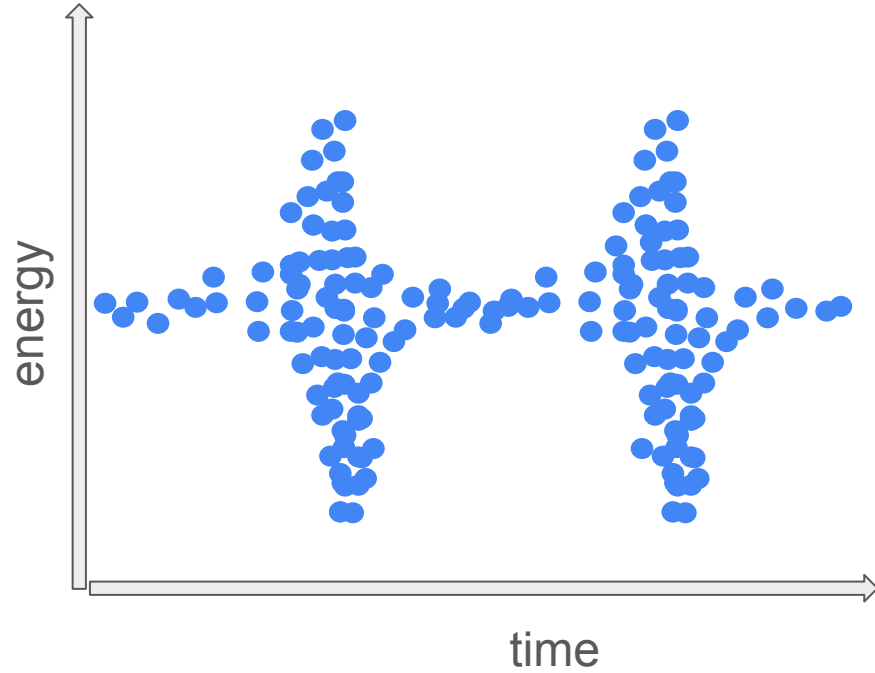
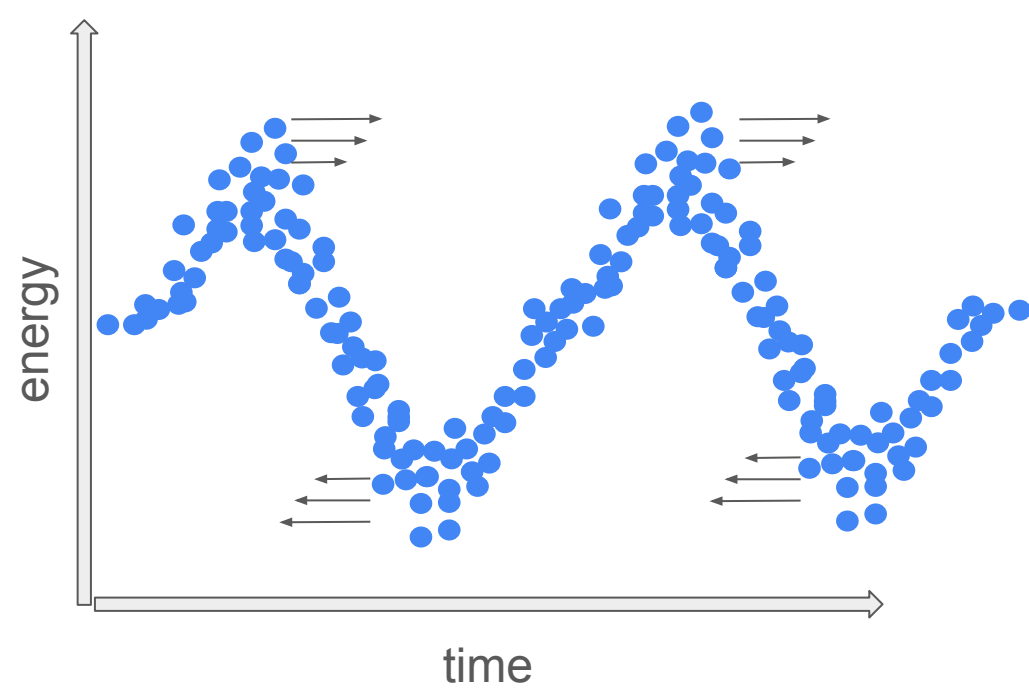
# Energy modulation



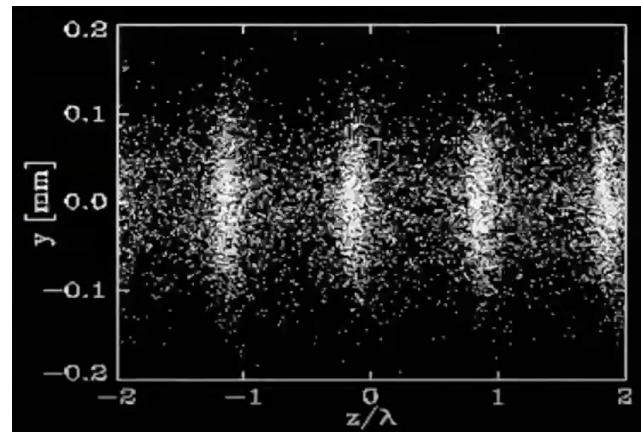
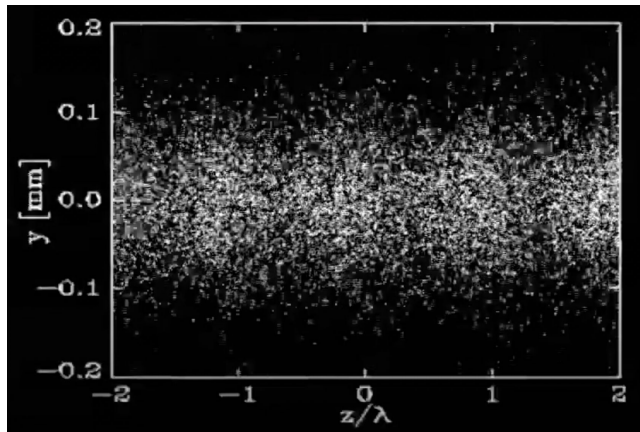
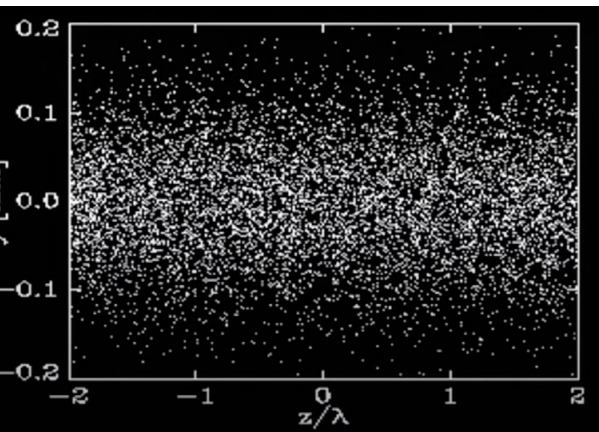


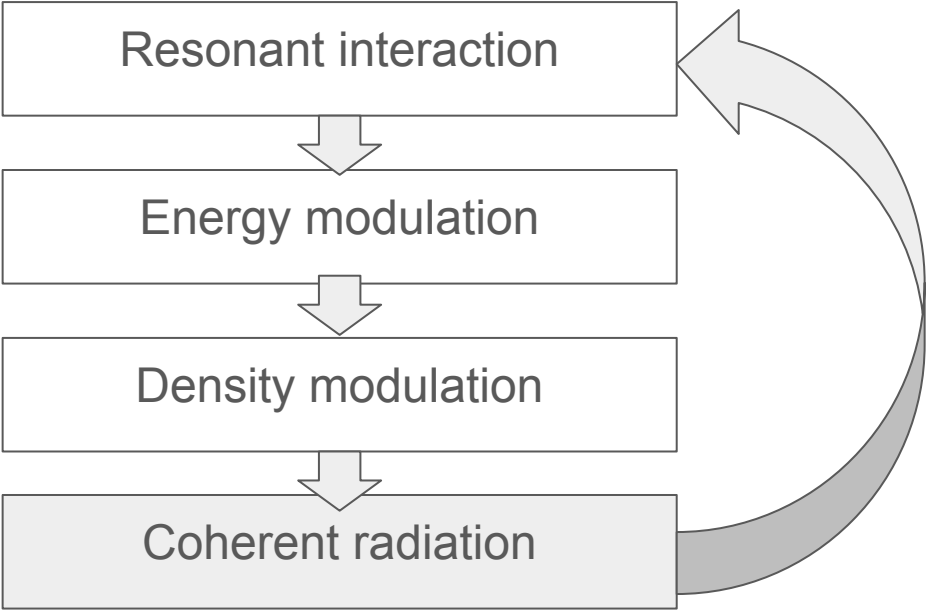
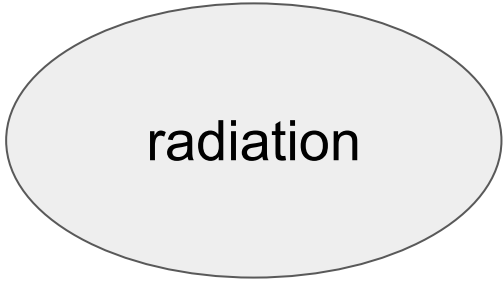


# Density modulation



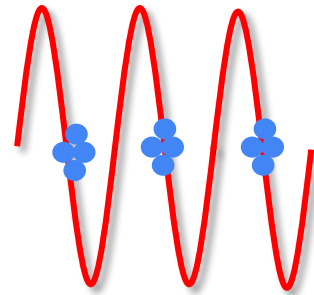
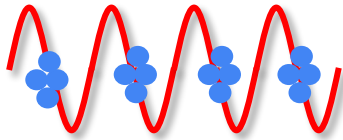
# Density modulation

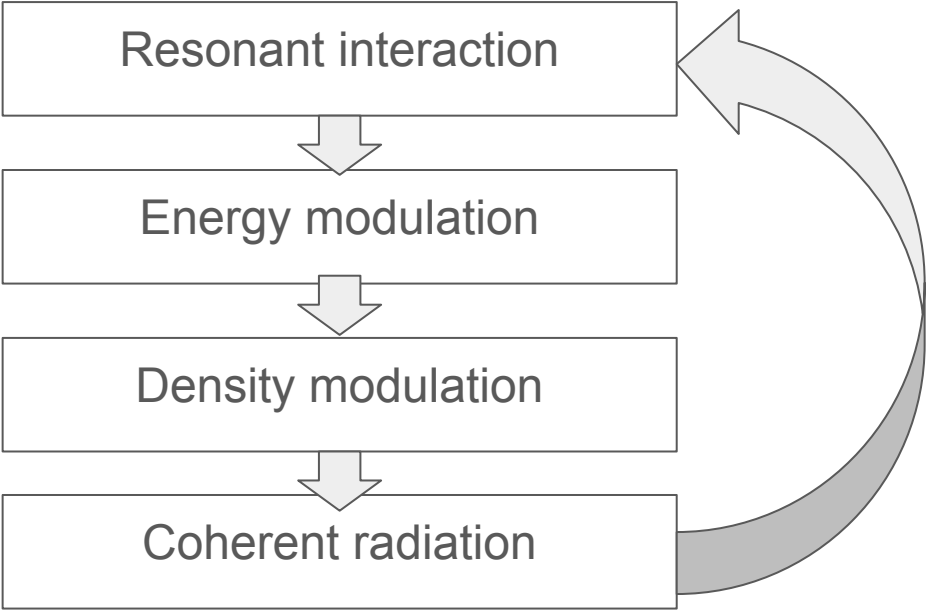
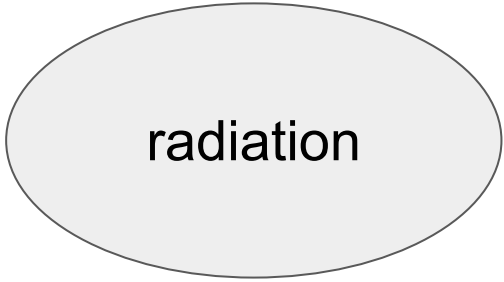




# Coherent radiation

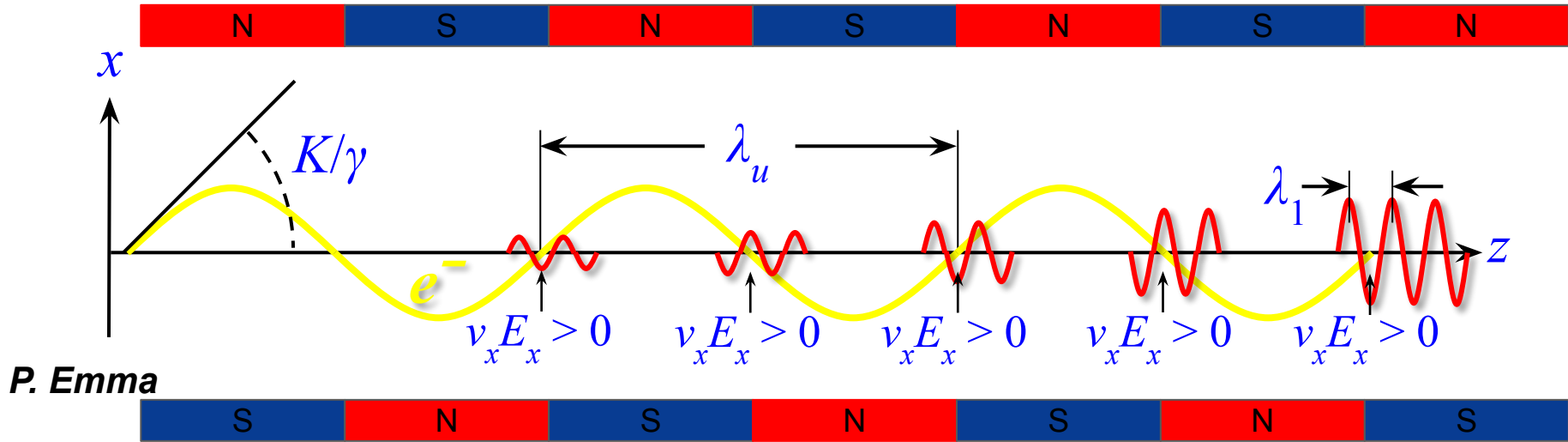
$$\text{power} \propto N^2$$





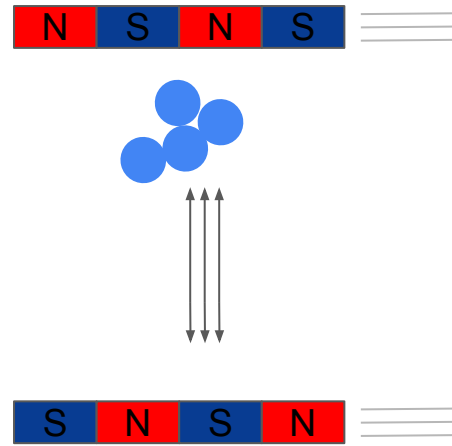
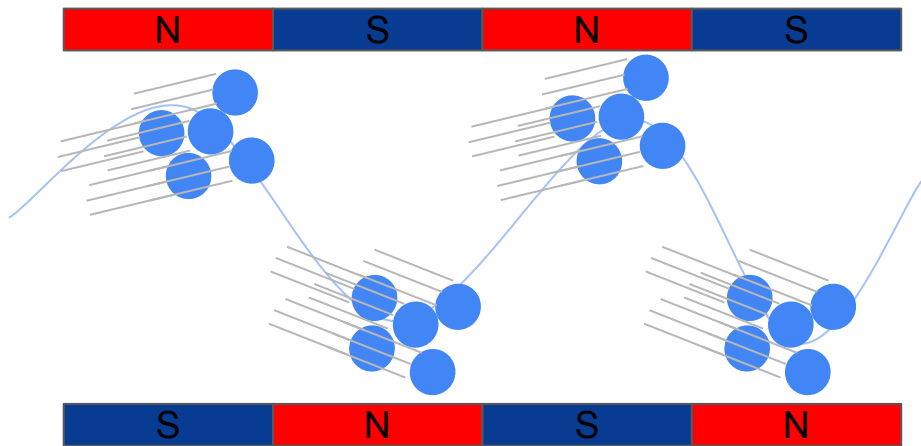
# Resonant interaction

Radiation slips ahead of the e- by  $\lambda_1$  per  $\lambda_u$ .



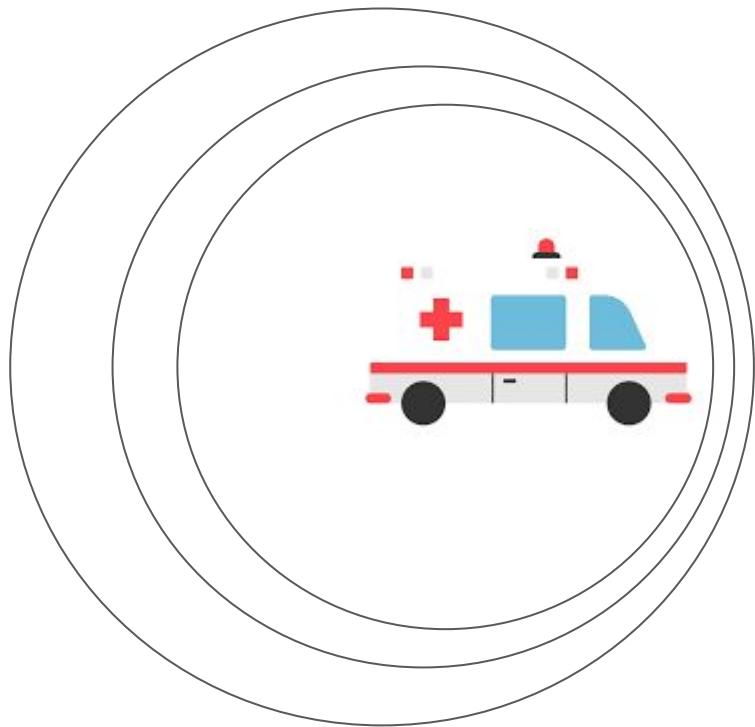
$$\lambda_1 = \frac{\lambda_u}{2\gamma^2} \left( 1 + \frac{K^2}{2} \right)$$

# The first $\gamma$ - special relativity

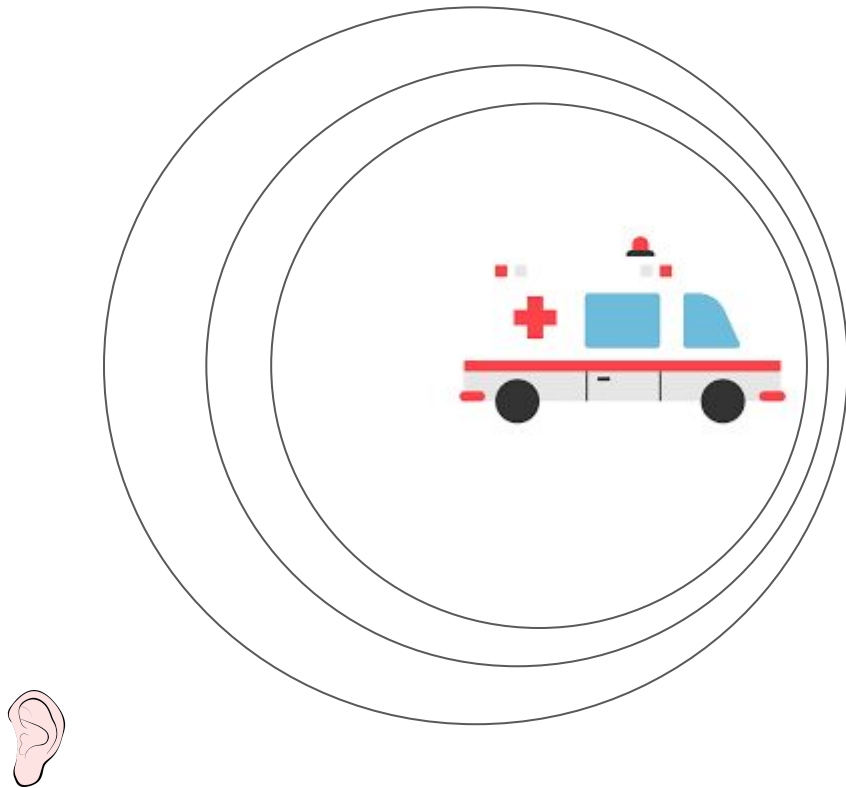




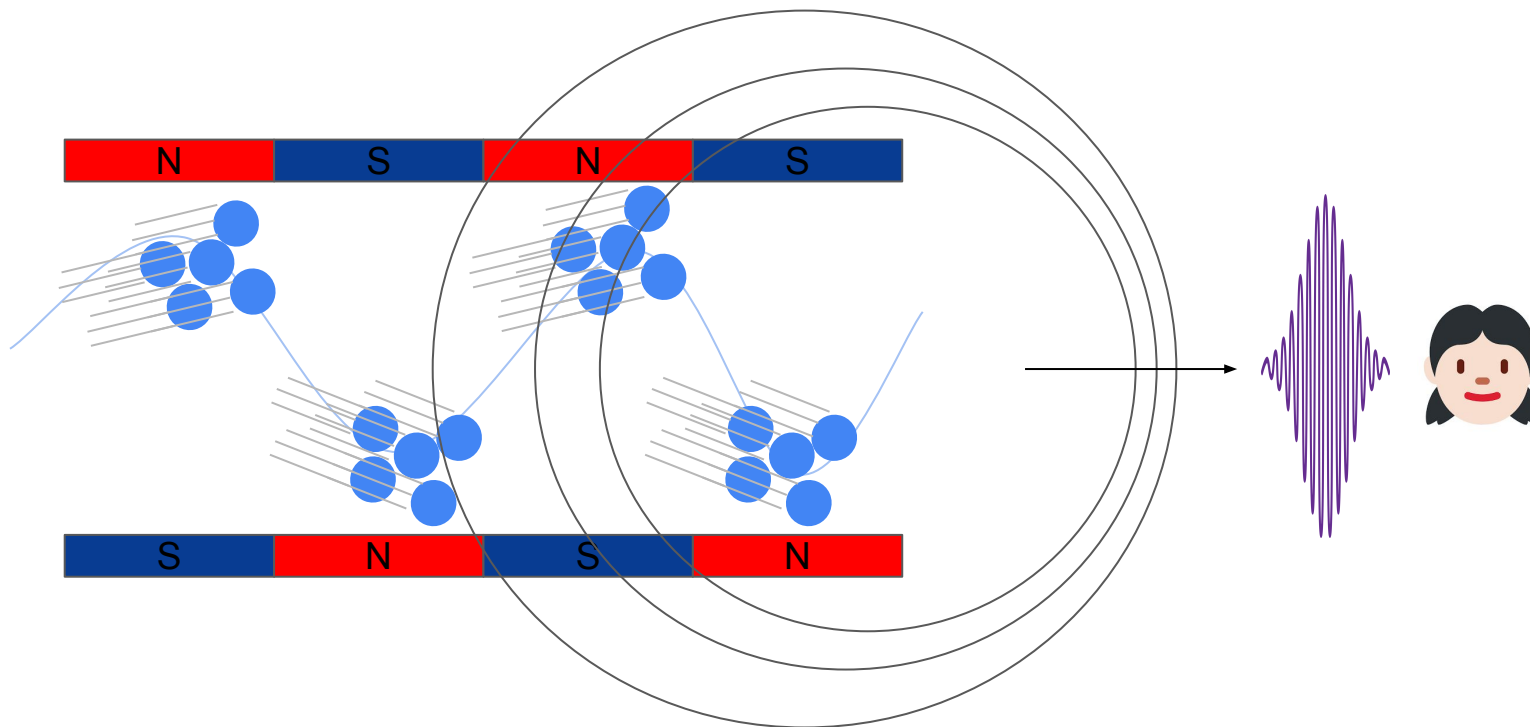
The second  $\gamma$  - the Doppler effect



## The second $\gamma$ - the Doppler effect



# The second $\gamma$ - the Doppler effect



$$\lambda_1 \propto \lambda_u / \gamma^2$$

Wavelength  
(meters)

Radio

$10^3$

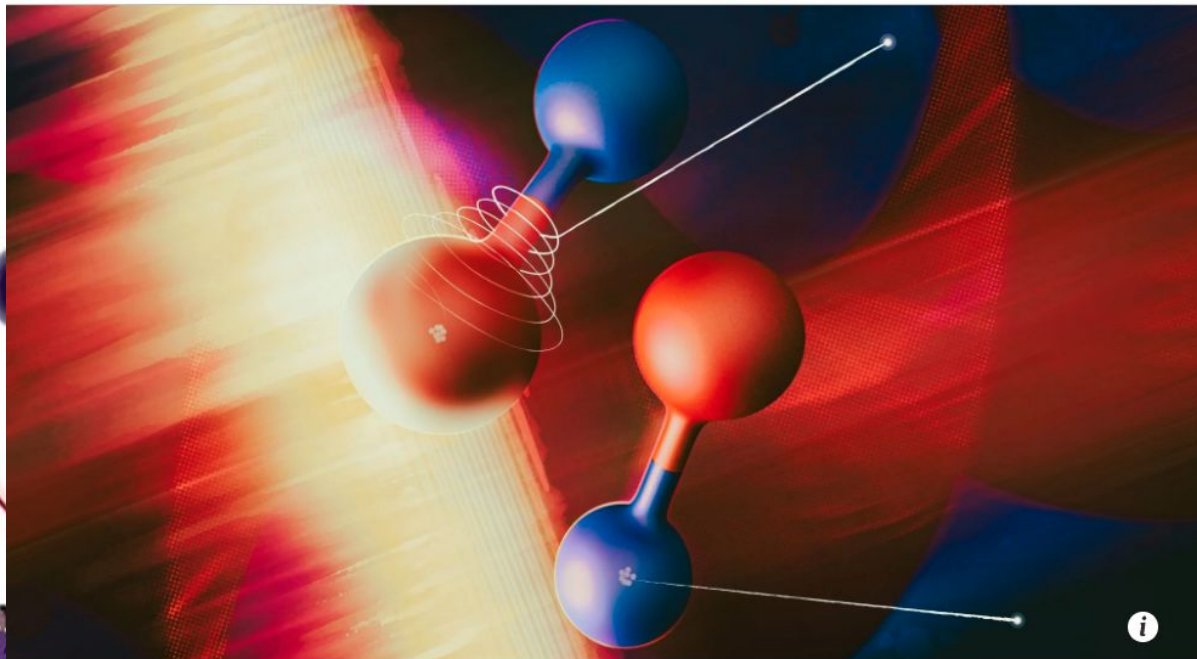
About the size of...



Buildings



Human



[Home](#) / [News and events](#) / [News center](#) / ...

AUGUST 21, 2024

## Scientists use attosecond X-ray pulses to shed new light on the photoelectric effect

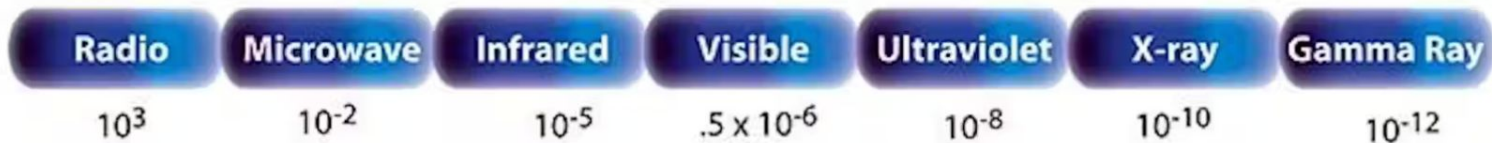
iclei

$$\lambda_1 \propto \lambda_u / \gamma^2$$

UH FEL  
40 MeV  
 $\gamma \sim 1e2$

LCLS  
4-11 GeV  
 $\gamma \sim 1e4$

Wavelength  
(meters)



About the size of...



Buildings



Humans



Honey Bee



Pinpoint



Protozoans



Molecules



Atoms



Atomic Nuclei

$$\lambda_1 \propto \lambda_u / \gamma^2$$

UH FEL

LCLS

4.11 GeV

PHYSICAL REVIEW ACCELERATORS AND BEAMS **22**, 040704 (2019)

## Free-electron laser inverse-Compton interaction x-ray source

Pardis Niknejadi,<sup>1,\*</sup> Jeremy M. D. Kowalczyk,<sup>1,†</sup> Michael R. Hadmack,<sup>1,2</sup>  
Bryce T. Jacobson,<sup>1,3</sup> Ian Howe,<sup>1</sup> Shidong Kan,<sup>1</sup> Steven Smith,<sup>1</sup> Eric B. Szarmes,<sup>1</sup>  
Gary Varner,<sup>1</sup> and John M. J. Madey<sup>1,‡</sup>

<sup>1</sup>*University of Hawai‘i at Mānoa, Department of Physics and Astronomy, Honolulu, Hawaii 96822, USA*

<sup>2</sup>*Oceanit, 828 Fort Street Mall, Honolulu, Hawaii 96813, USA*

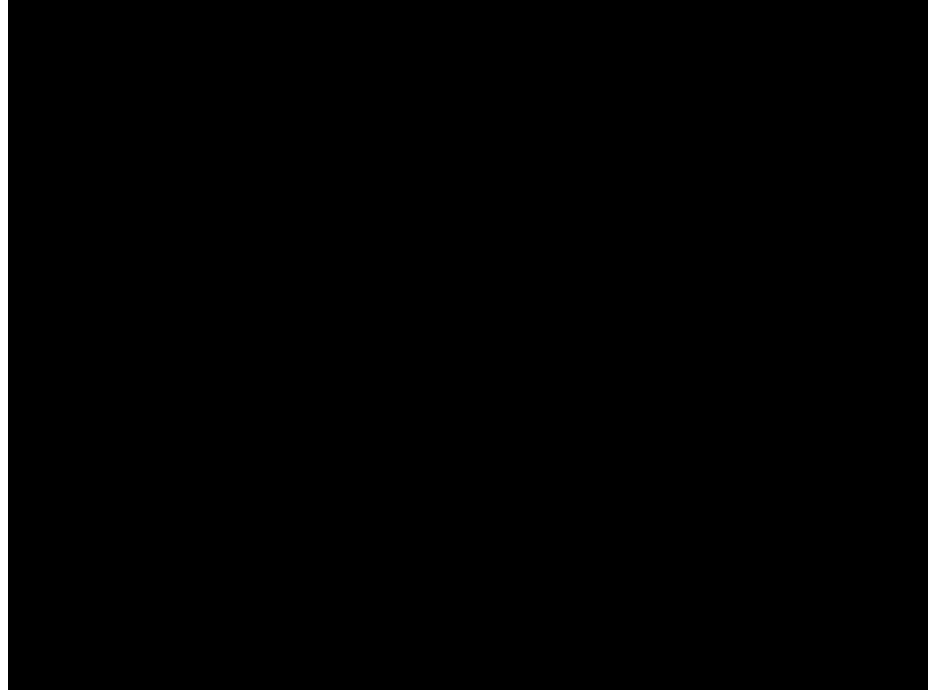
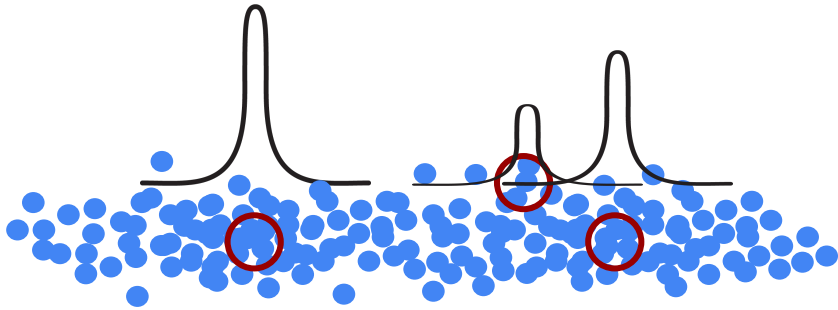
<sup>3</sup>*SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA*



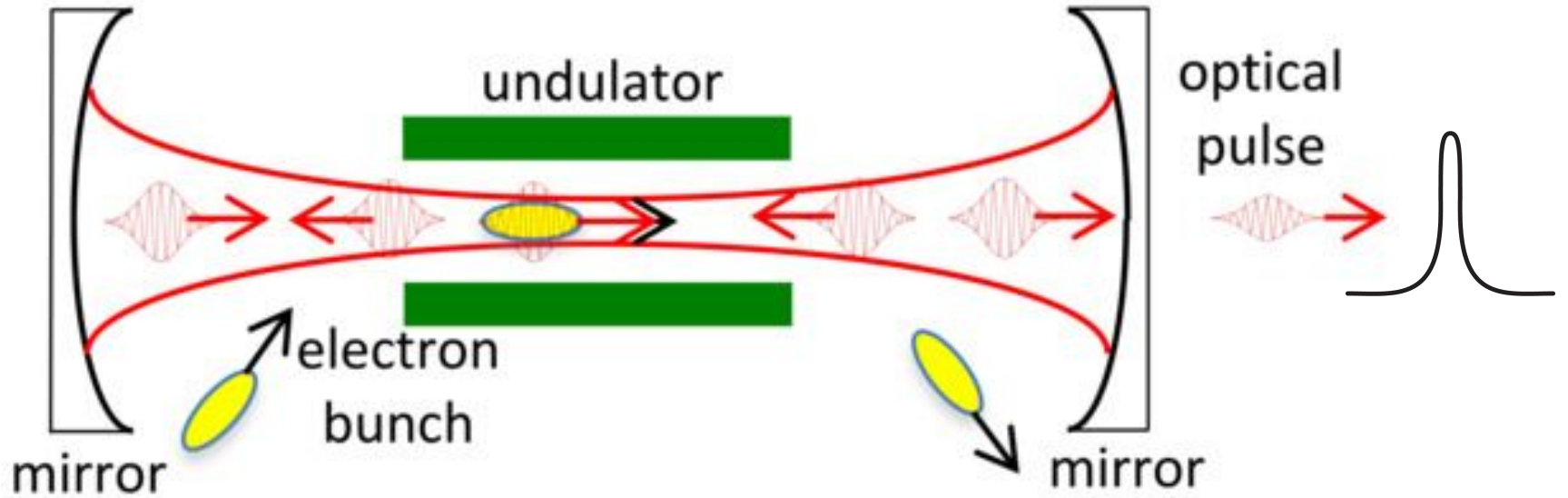
(Received 11 February 2019; published 29 April 2019)

Wave

FEL starts from shot noise - a stochastic process



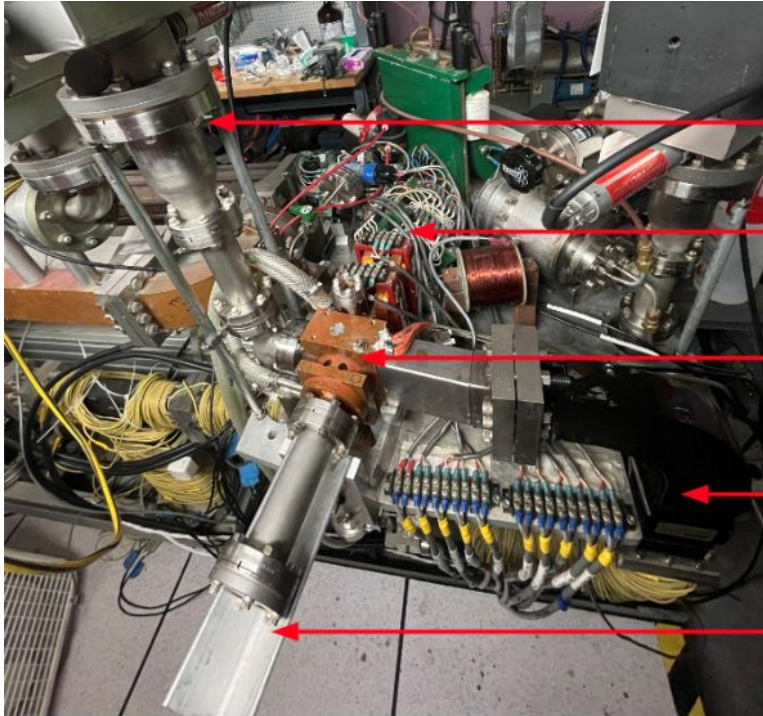
# FEL oscillator





## Research projects:

- Switch on the accelerator!
  - Vacuum checks
  - Replace and repair



4<sup>th</sup> step, leak on the vacuum column:  
Ion Pumps = 2.5 mA -> 5 mA

3<sup>rd</sup> step, leak near Gun Toroid1:  
Ion Pumps = 2.5 mA -> 3 mA

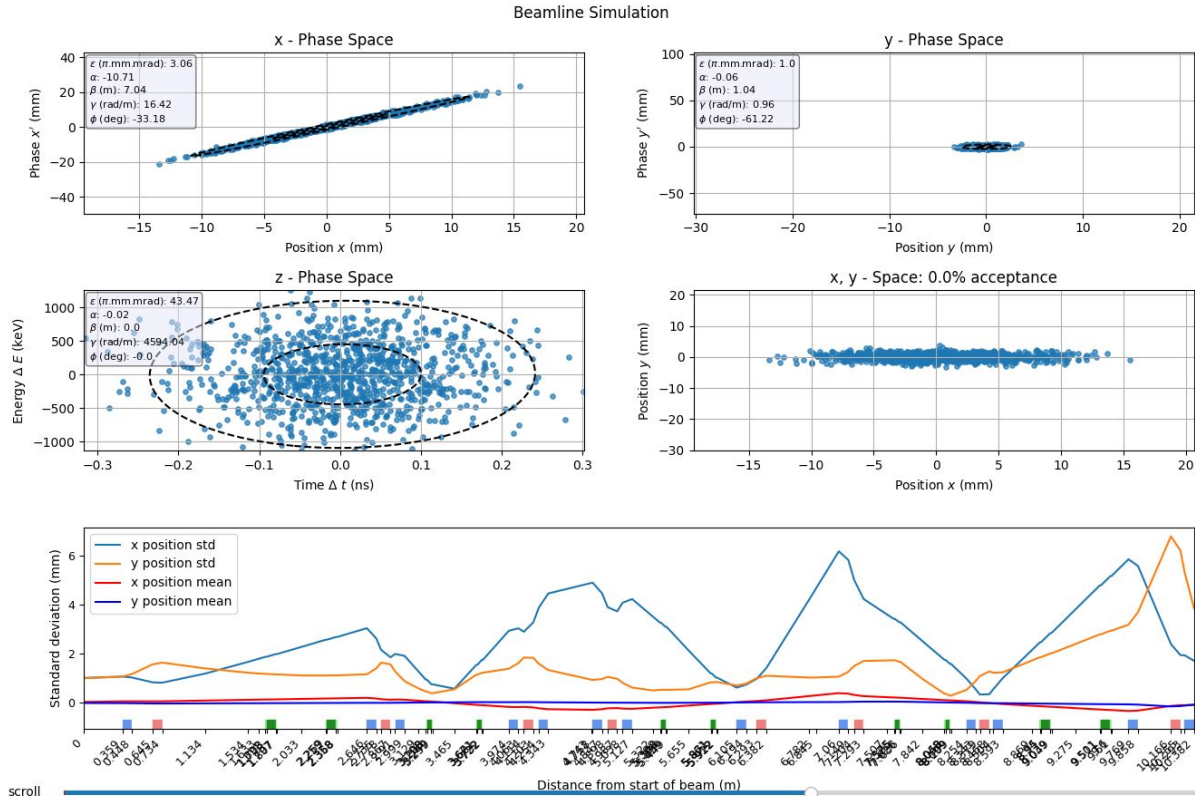
2<sup>nd</sup> step, bake-out:  
Ion Pumps = 150  $\mu$ A -> 2.2 mA

Leak detected on the Waveguide

1<sup>st</sup> step, cathode removal:  
Ion Pumps = 120  $\mu$ A -> 130  $\mu$ A

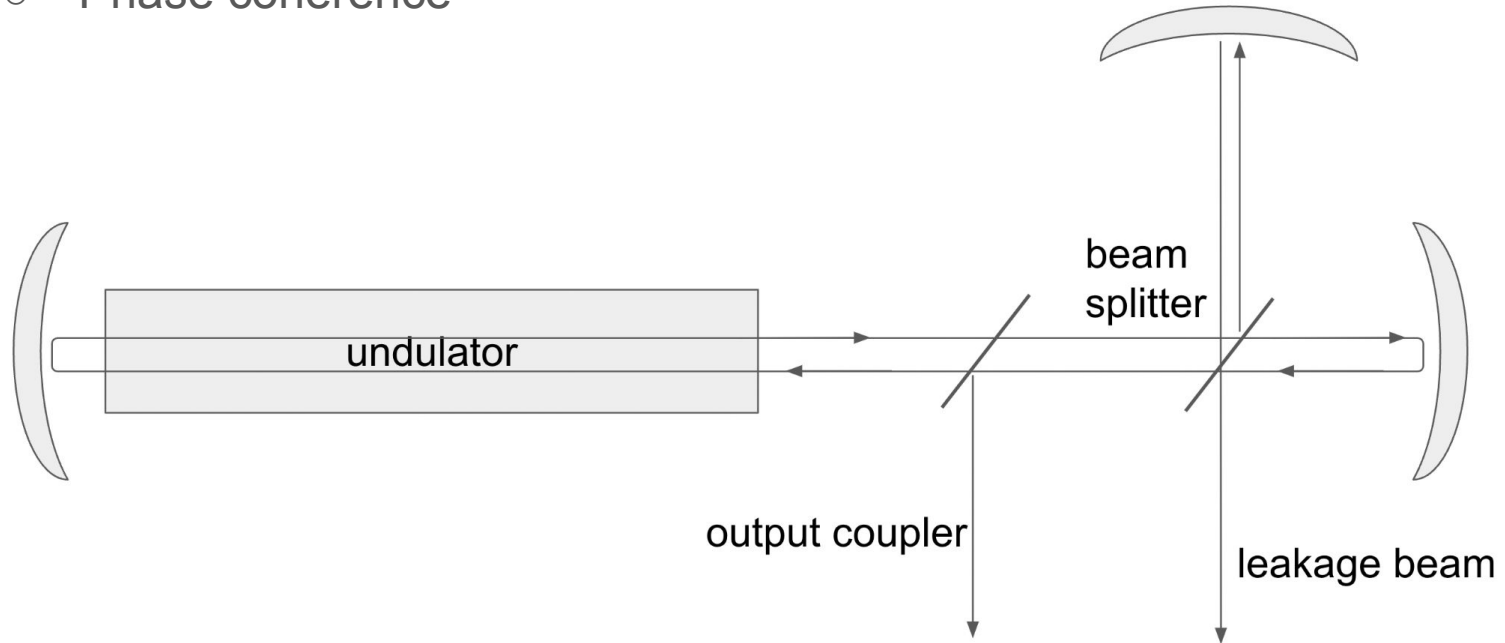
# Research projects:

- Beam simulation



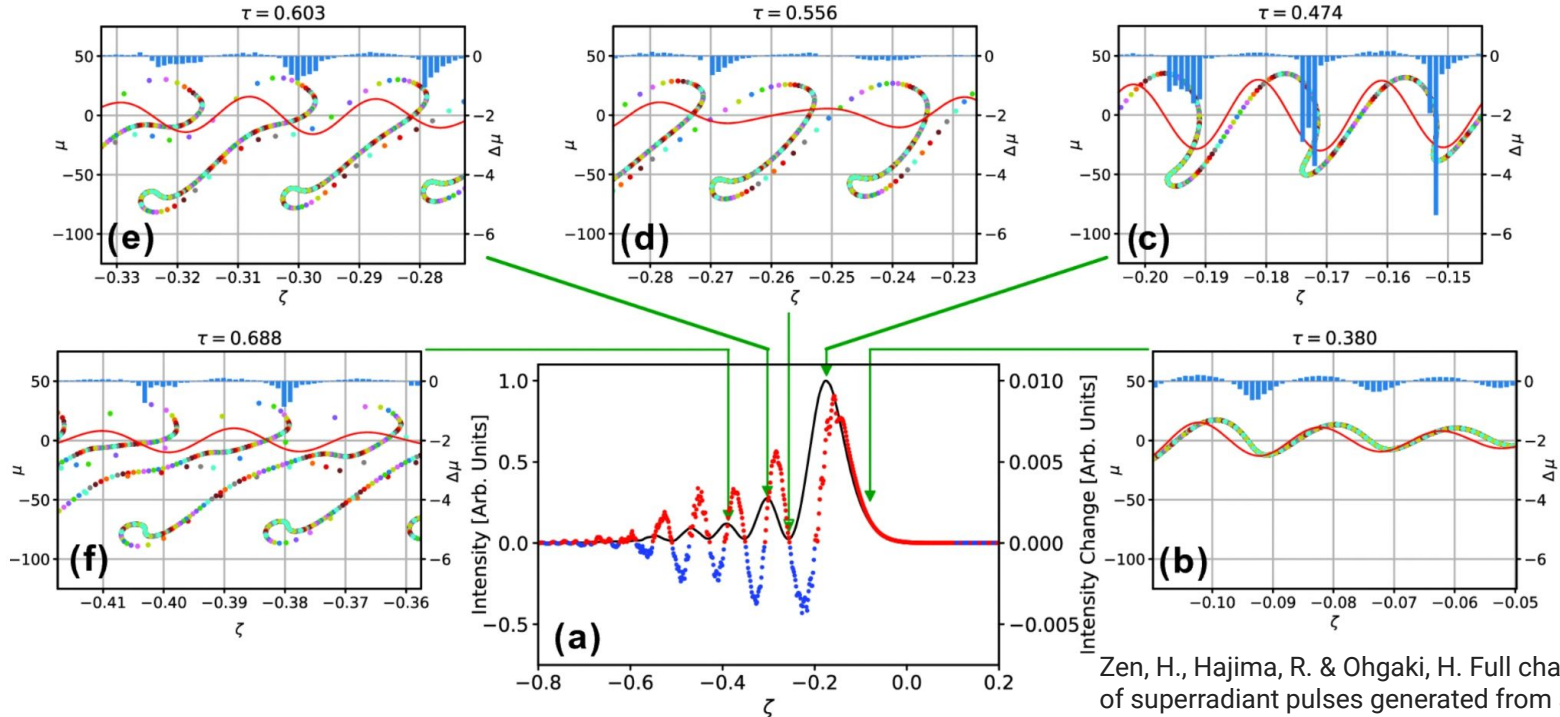
## Research projects:

- 3D simulation of the FEL oscillator
  - Phase coherence



# Research projects:

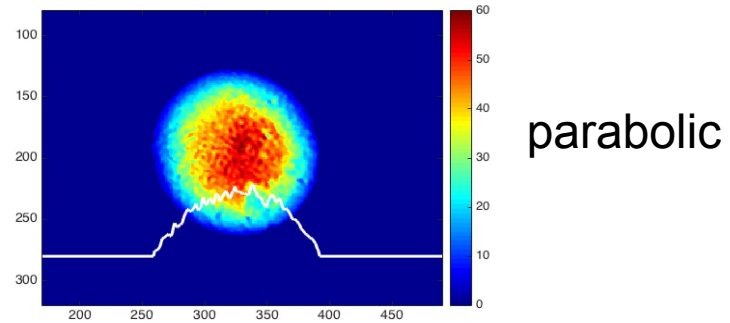
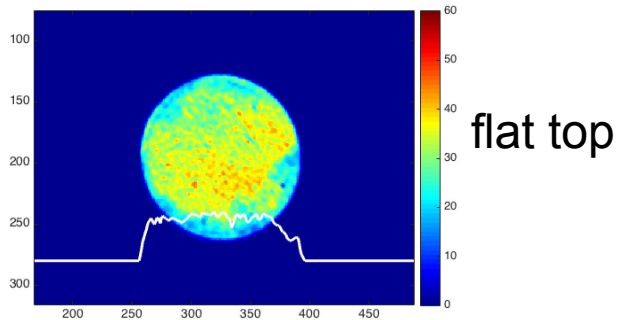
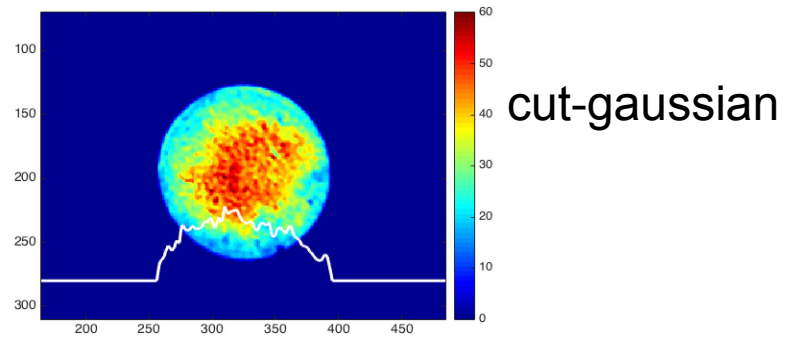
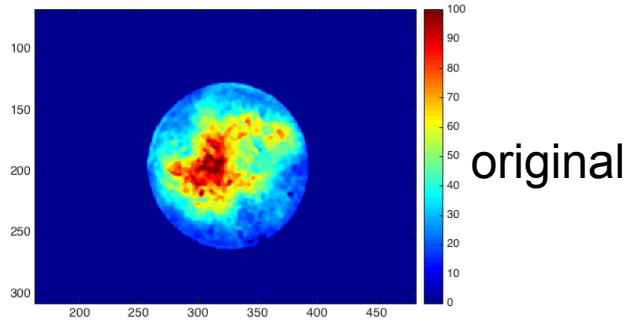
- 3D simulation of the FEL oscillator
  - superradiance



Zen, H., Hajima, R. & Ohgaki, H. Full characterization of superradiant pulses generated from a free-electron laser oscillator. *Sci Rep* 13, 6350 (2023).

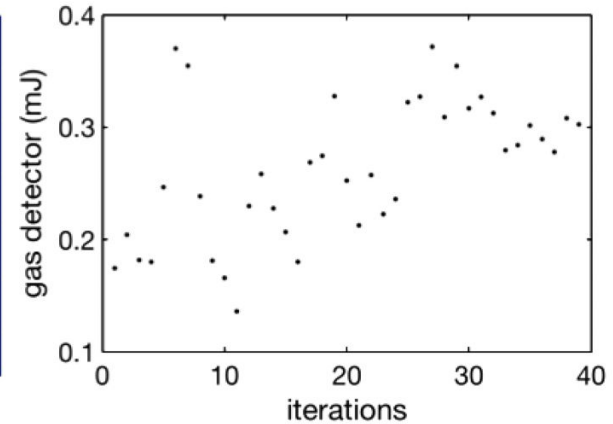
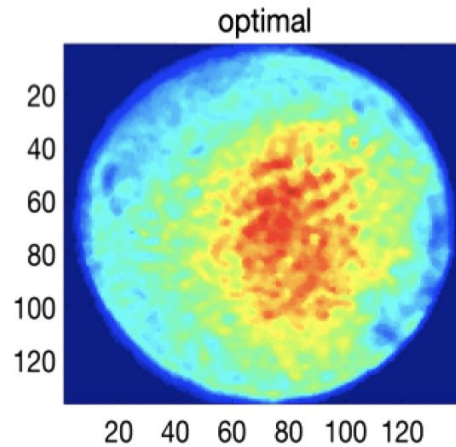
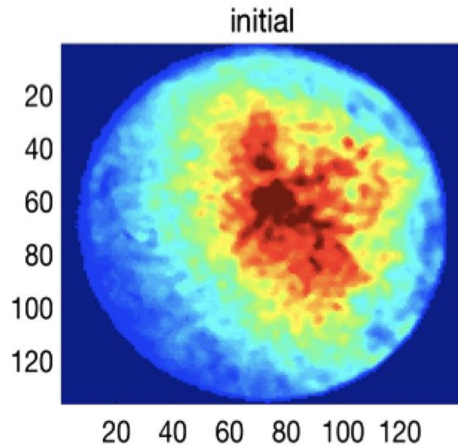
# Research projects:

- Beam shaping



## Research projects:

- Controls upgrade
- AI/ML



Li, S., et al. "Ultraviolet laser transverse profile shaping for improving x-ray free electron laser performance." *Physical Review Accelerators and Beams* 20.8 (2017): 080704.

# Resources

- Possible course on accelerator physics Fall 2025.
- USPAS, every winter and summer
- Lee Teng undergraduate internship
- Contact us for tour

Niels Bidault

WAT 205

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Siqi Li

WAT 206

[siqili@hawaii.edu](mailto:siqili@hawaii.edu)



The screenshot shows the website for the U.S. Particle Accelerator School. The header features the school's logo and name, along with a search bar. The navigation menu includes links for Home, About, Programs, Courses, Materials & Instructors, Resources, Opportunities, Photos, and Contact. The main content area is titled "Winter 2025 USPAS Session" and includes a prominent "APPLY NOW" button. Below this, there are sections for "University Sponsor" (Michigan State University), "Location & Dates" (Knoxville, Tennessee, USA, January 27 - February 7, 2025), and "Deadline Dates" (Application deadline for all attendees and deadline for scholarship supporting documents: October 1, 2024). A paragraph explains that the following courses run in parallel, allowing students to take one 2-week full course or two 1-week half courses. A list of "Two-week full courses" is provided, including "Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab" (undergrad level) and "Accelerator Physics".

**U.S. Particle Accelerator School**  
Education in Beam Physics and Accelerator Technology

Home About Programs Courses, Materials & Instructors Resources Opportunities Photos Contact

### Winter 2025 USPAS Session

**University Sponsor:** Michigan State University [APPLY NOW](#)  
[General Information and Details](#)

**Location & Dates:** Knoxville, Tennessee, USA  
January 27 - February 7, 2025

**Deadline Dates:** Application deadline for all attendees and deadline for scholarship supporting documents: October 1, 2024

The following courses run in parallel so students may take one 2-week full course OR two 1-week half courses. Each two-week course is eligible for 3 units of credit from Michigan State University.

**Two-week full courses: January 27 - February 7, 2025**

- **Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab (undergrad level)**  
**Instructors:** Simon C. Leemann, Lawrence Berkeley National Lab; Thomas Schietinger, Paul Scherrer Institute; Ryan Lindberg, Argonne National Lab  
**TA:** John Wieland, Michigan State University  
*This class is limited to 30 students*
- **Accelerator Physics**  
**Instructors:** S. Alex Bogacz, Jefferson Lab; Geoff Krafft, Old Dominion University and Jefferson Lab; Subashini De Silva, Old Dominion University and Isurumali Neththikumara, Jefferson Lab  
*This class is limited to 20 students*
- **RF Superconductivity for Particle Accelerators**  
**Instructors:** Sergey Belomestnykh, Fermilab; Silvia Verdu Andres, Brookhaven National Lab  
*This class is limited to 20 students*

## Programs

[Current Program](#)

[Next Program](#)

[IU/USPAS Master's Degree](#)

[USPAS-Affiliated  
University Credits](#)

[Joint International  
Accelerator School](#)

[University-Style Programs](#)

[Symposium-Style Programs](#)

# Resources

- Possible course on accelerator physics Fall 2025.
- USPAS, every winter and summer
- Lee Teng undergraduate internship
- Contact us for tour

Niels Bidault

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Siqi Li

WAT 206

[siqili@hawaii.edu](mailto:siqili@hawaii.edu)



## Internship programs

High School	>
Undergraduate	∨

Accelerator Engineering Fellowships for Underrepresented Minorities (ASPIRE)

Business Intern Program (BIP)

\*Community College Internships (CCI)

Cooperative Education Program

Fermilab and Brookhaven Summer School Exchange Program

Fermilab Environmental Management Internship (EMMI)

## Lee Teng Undergraduate Internship

### Program Description

The Lee Teng Undergraduate Internship in Accelerator Science and Engineering is a joint 10-week program between Argonne National Laboratory and Fermilab, established by the Illinois Accelerator Institute to attract undergraduate students into the exciting and challenging world of particle accelerator physics and technology. A limited number of highly qualified students will be selected into this program. Successful candidates will attend the Summer Session of the *U.S. Particle Accelerator School (USPAS)*. All interns will take the *Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab* for which 3 units of undergraduate credit is available. For the remainder of the summer, interns will work closely with a mentor and a project at either Argonne National Laboratory or Fermilab.

For more information, visit <https://www.illinoisacceleratorinstitute.org/>.

### Key Dates

#### Application Dates

TBD

### Application is Closed

Apply

Chrome (preferred browser)