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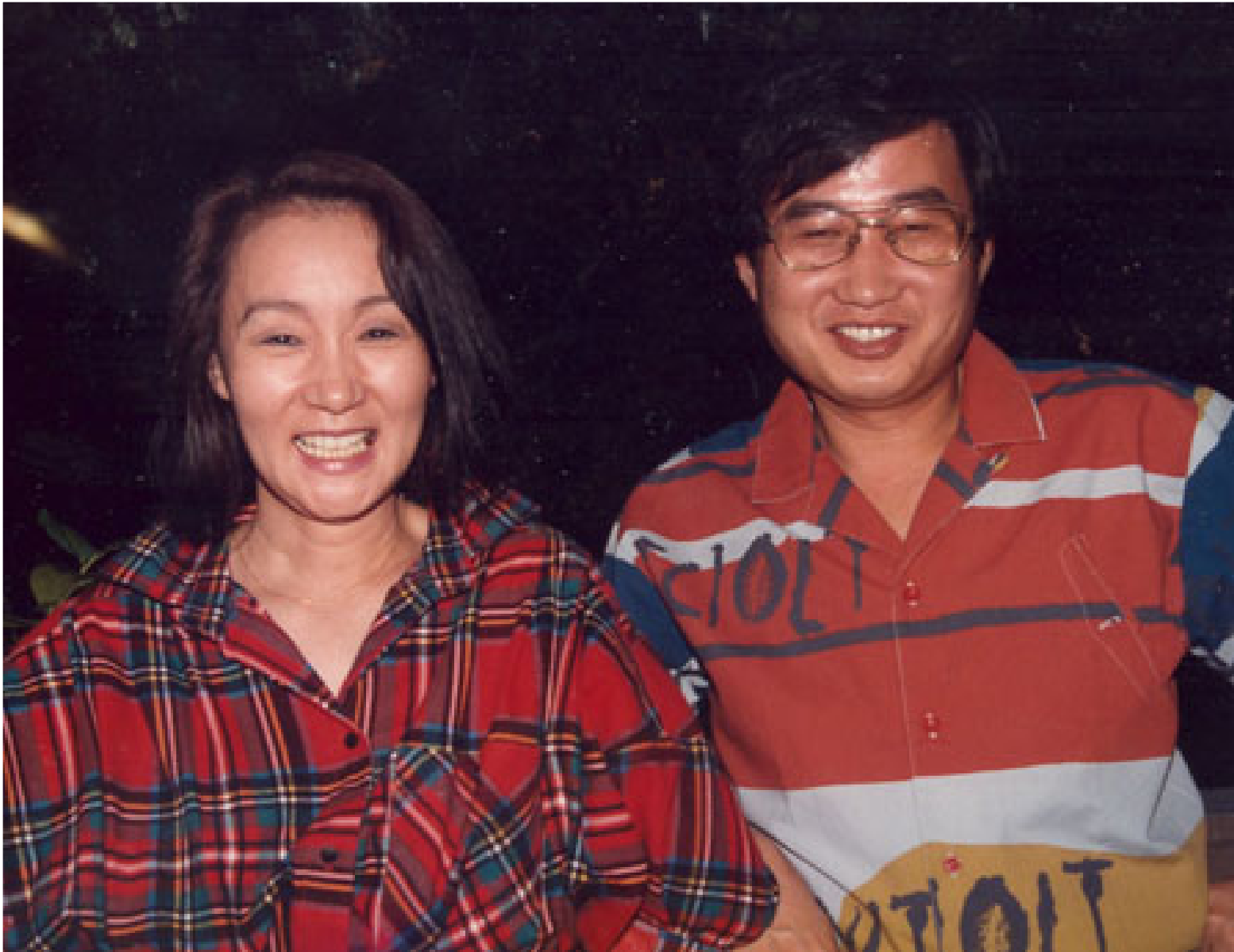
# Brightness and Coherence Research at the Center for X-Ray Optics

David Attwood  
University of California, Berkeley

# Happy days in Berkeley



# Happy Couple: Kwang-Je and Kyeong-Hwa aka Elizabeth



# The Impossible Dream- The ALS in Berkeley



Happiness delayed





# Center for X-Ray Optics (CXRO) formed, Fall 1983



## LBL Starts World's First Center For X-ray Optics

By Lynn Yarris

The only one of its kind in the world, LBL's new Berkeley Center for X-Ray Optics is scheduled to begin full operation in April, as part of the Accelerator and Fusion Research Division.

Under the leadership of physicist David Attwood, research at the new Center will focus on the use of radiation that falls between x-rays and ultraviolet light (about 10 keV to 10 eV) on the electromagnetic spectrum—often referred to as XUV radiation.

"The Center will serve as a national source of development and application of new techniques for the

use of XUV radiation," says Attwood. "Emphasis will be placed on emerging technologies, such as diffractive and reflective optics, necessary for the efficient transport, dispersion, focusing and detection of XUV radiation from synchrotron and other light sources."

The relatively unexplored XUV spectral region has been called the last frontier of the electromagnetic spectrum. According to Attwood, "After a 30-year dormancy, interest in the region has suddenly come alive."

The reason for this renaissance, he says, is a rapid advancement in technological capabilities, permitting

exciting new applications of XUV radiation and optics in the fields of physics, chemistry, materials science, and the biological and life sciences.

Potential applications include the development of x-ray microscopes that could provide detailed views of materials and biological structures, such as cells, never before attainable, and the production of much smaller microcircuits for the electronics

industry than is currently possible. In addition, says Attwood, devices, such as LBL's Advanced Light Source, which is so rich in atomic resonance structure."

which is so rich in atomic resonance structure."

The idea of a center specializing in the study of XUV radiation through x-ray optics was first proposed at the June 1981 Monterey Conference on Low-Energy X-Ray Techniques, sponsored by the American Institute of Physics.

Organized by Attwood and University of Hawaii physicist Burton

**currents**

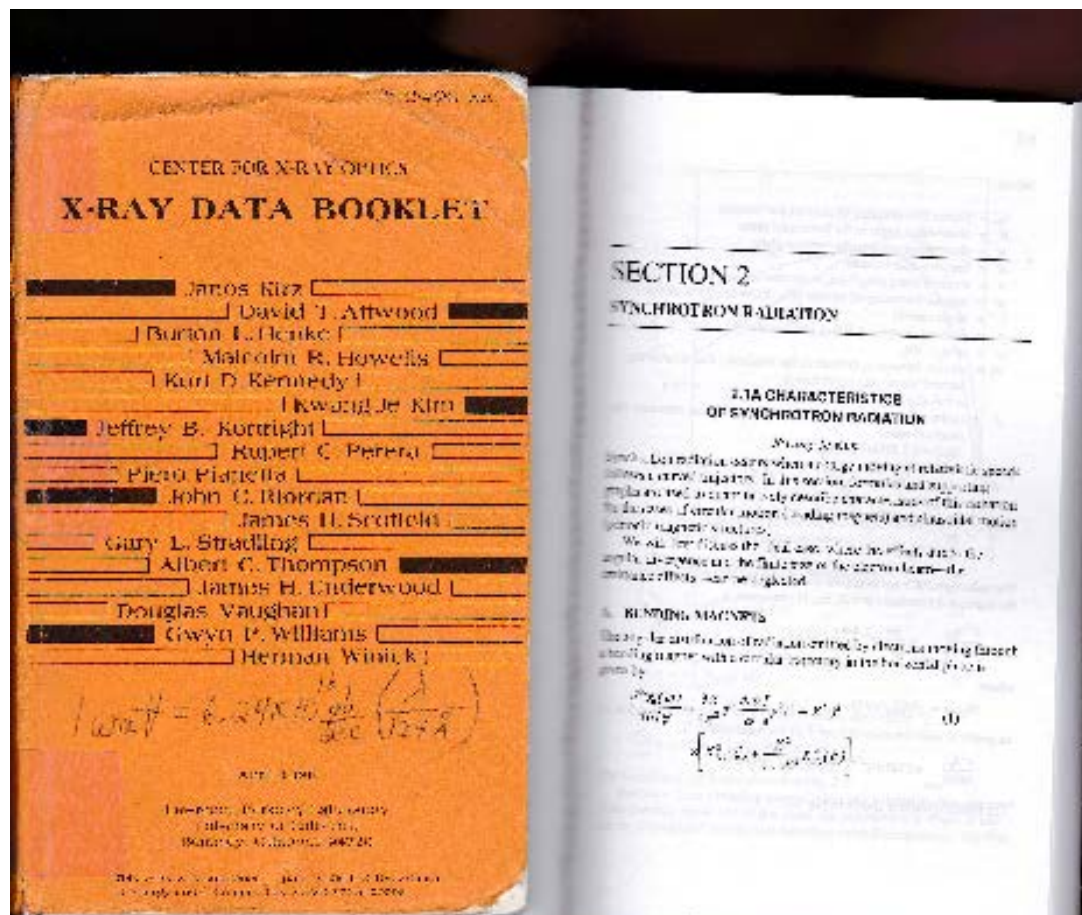
**LAWRENCE**

University of California Berkeley, California 94720



Vish More of Plant Engineering (center, at desk) describes the laboratory facilities which will soon be available at LBL's new Center for X-ray Optics. Behind More are, from left to right, David Attwood, consultant Gary Sommargren of Zygo Corporation, James Underwood, Kwang-Je Kim, Malcolm Howells and Al Thompson.

# Orange Data Book, April 1986



## Center for X-Ray Optics 1986

Accelerator and Fusion Research Division  
Lawrence Berkeley Laboratory  
University of California  
Berkeley, California 94720

July 1987

This work was supported by the U.S. Department of Energy, Office of Basic Energy Sciences under Contract DE-AC02-76SF00030, and the U.S. Department of Defense, Air Force Office of Research and Development under Grant F49620-87-1-0001.

LBL 23795  
UC-81A

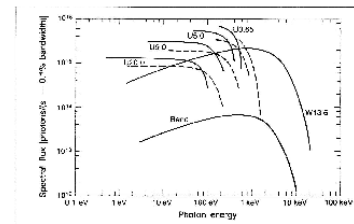
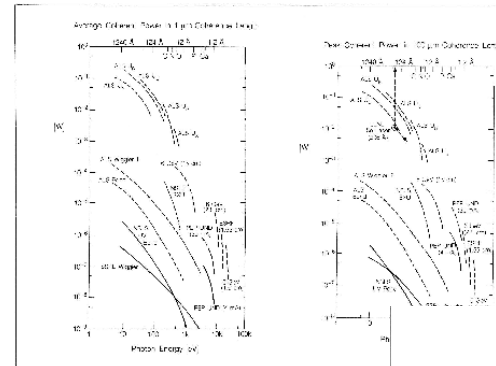


Fig. 2. Spectral brightness as a function of energy for four possible undulators, assuming  $\beta = 0.9999999999$ , and the bending magnets of the advanced light source. For the undulators, the bending magnets are shown for both the fundamental (solid line) and the first harmonic (dashed line).

### High-Gain Free-Electron Lasers

Electrons passing through a simple undulator are initially uncorrelated, and they remain uncorrelated as they continue along the device. As the number of the undulator periods,  $N$ , increases, however, the interaction between the undulator radiation and the electron beam can lead to density modulations—“bunching”—in the electron beam and to an exponential amplification of the radiation. The undulator thus becomes a so-called high-gain free-electron laser (FEL), and the radiation emitted is called self-amplified spontaneous emission (SASE) by analogy to laser terminology. The transition from simple undulator to high-gain FEL is illustrated schematically in Fig. 3.

Since high-gain FELs operating in the SASE regime do not require the use of high-reflectivity mirrors to form optical cavities, they are promising alternatives to FEL oscillators as generators of intense, coherent radiation at wavelengths shorter than 1000 angstroms. At microwave wavelengths, the principle of SASE has been experimentally confirmed at the Lawrence Livermore National Laboratory.

Recently, we have made substantial progress in understanding how SASE emerges and propagates in long undulators. Our analysis, based on the Maxwell-Klein-Gordon equation, differs from earlier work in two respects. First, we use a microscopic description of electrons in terms of the Klein-Gordon particle distribution function. Second, the analysis is three-dimensional so that important issues such as guiding and transverse coherence can be clarified. Finding an explicit expression for the amplitude of the coherent amplification in terms of the input amplitude was a hitherto unsolved problem in three dimensions.

An important parameter characterizing high-gain FELs is the dimensionless parameter  $\rho$ , which is typically of order  $10^5$ . Figure 3 summarizes the evolution of simple undulator radiation to SASE. For  $\rho \ll 1$ , the radiation is an incoherent superposition of radiation from individual

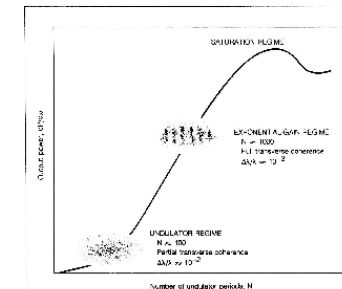


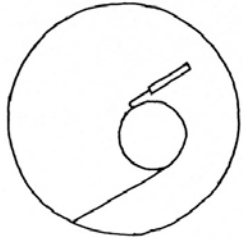
Fig. 3. Schematic diagram of the evolution from simple undulator to high-gain free-electron laser. The appearance of electron “bunching” is accompanied by an exponential gain in the intensity of emitted radiation. Saturation follows when electron motion ceases to remain in phase with the wavelength of the emitted light.



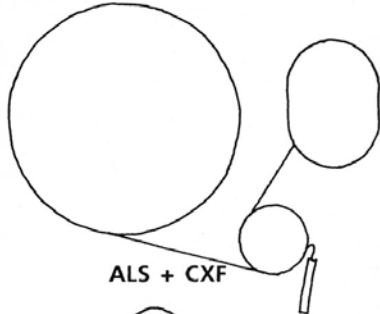
# Kwang-Je Kim's FEL designs



## Facility Options - ALS and/or CXF

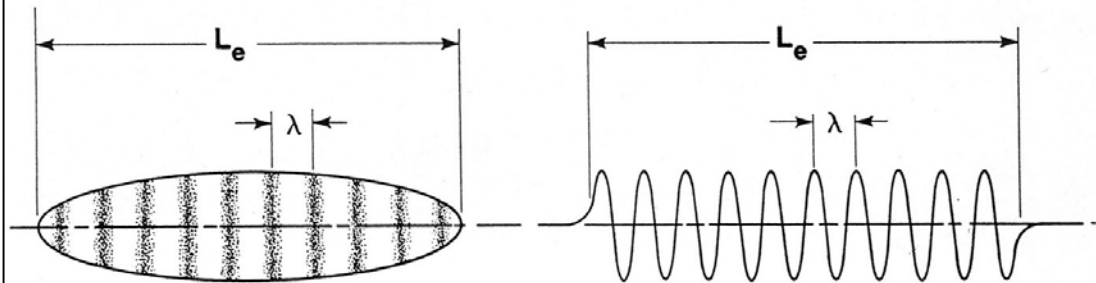


ALS (1.3 GeV and 1.9 GeV)

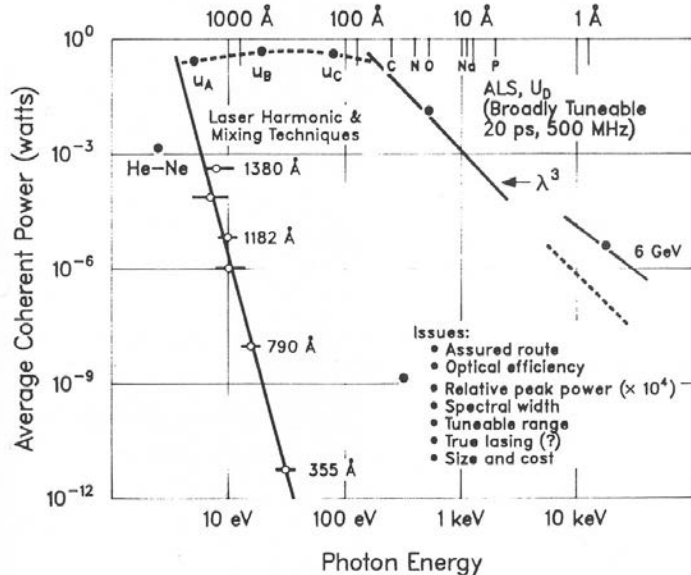


ALS + CXF

## FEL Operation in a Low Emittance, High Current Ring (CXF) Would Provide Fully Coherent Radiation at Wavelengths Shorter Than 1000 Å



### BROADLY TUNEABLE COHERENT POWER\* WILL BE AVAILABLE IN AN INTERESTING SPECTRAL REGION



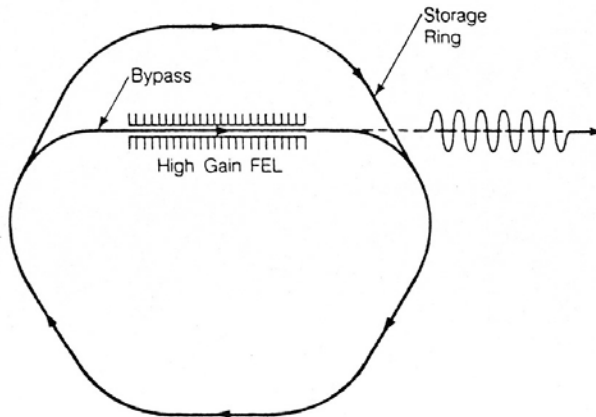
\*Full spatial coherence; longitudinal coherence  $\geq 1 \mu\text{m}$

- Radiation couples to electron beam and modulates the density with period length  $\lambda$
- Coherent addition of radiation from different electrons — Intensity is proportional to  $N_e^2$ .
- Longitudinal coherence  $l_c = L_e \left( \frac{\lambda}{\Delta\lambda} \right) \approx \frac{L_e}{\lambda} \approx 10^6$
- Spatially coherent and tuneable.

AFRO 0585-5035



## High-Gain, Single-Pass Free Electron Laser

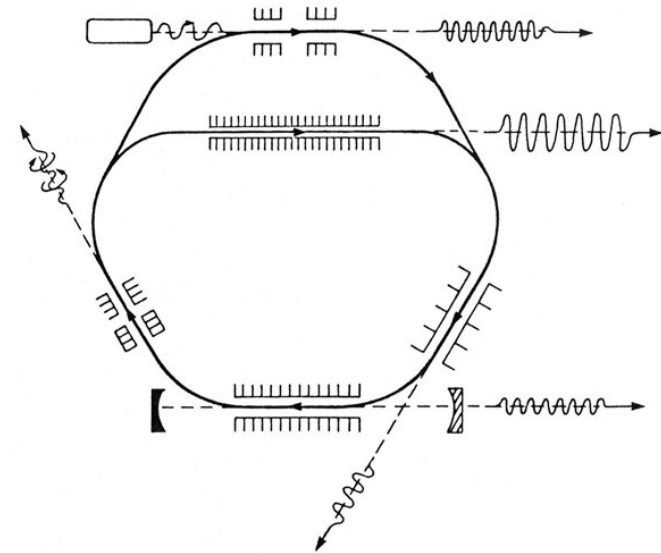


- FEL interaction is so strong that an intense, coherent signal develops from noise in a single pass.
  - Mirrors are not required.
- Long undulator ( $\sim 20$  m; 500–1000 periods) with small gap ( $\sim 3$  mm) requires bypass operation.
- Tens of megawatts of peak power is expected.

## An FEL Community White Paper Was Organized

### Coherent X Rays and Vacuum-Ultraviolet Radiation from Storage-Ring-Based Undulators and Free Electron Lasers

December 1984



# A New Scientific Case for the ALS Based On Coherence and Nanoscale Science



14 June 1985, Volume 228, Number 4705

## SCIENCE

June 1985

### Tunable Coherent X-rays

David Attwood, Klaus Halbach, Kwang-Je Kim

The spectral region referred to as the XUV includes soft x-rays and ultraviolet radiation. Photon energies in this region extend from several electron volts (eV) to several thousand electron volts (keV). The primary atomic resonances of elements such as carbon, oxygen, nitrogen, and sodium, as well as resonances from many molecular transitions, appear in this region. In addition, the photon

which emit radiation of longer wavelengths. Optical techniques, including reflection, dispersion, and imaging, suffer from photoelectric absorptive effects in this region. Between the wavelengths of about 10 and 1000 angstroms ( $\text{\AA}$ ) there are no materials that are both transmissive and capable of supporting an atmosphere of pressure over macroscopic dimensions.

**Summary.** A modern 1- to 2-billion-electron-volt synchrotron radiation facility (based on high-brightness electron beams and magnetic undulators) would generate coherent (laser-like) soft x-rays of wavelengths as short as 10 angstroms. The radiation would also be broadly tunable and subject to full polarization control. Radiation with these properties could be used for phase- and element-sensitive microprobing of biological assemblies and material interfaces as well as research on the production of electronic microstructures with features smaller than 1000 angstroms. These short wavelength capabilities, which extend to the K-absorption edges of carbon, nitrogen, and oxygen, are neither available nor projected for laboratory XUV lasers. Higher energy storage rings (5 to 6 billion electron volts) would generate significantly less coherent radiation and would be further compromised by additional x-ray thermal loading of optical components.

wavelengths in this region match important spatial scales such as the pitch and diameter of biochemical helices, the microstructural features of materials, and the dimensions of the next generation of electronic microcircuits.

Substantial progress in the development of x-ray optical techniques has been made recently (1-6), largely as the result of the need for ever smaller microfabrication capabilities in the electronics industry, research on x-ray emitting, hot

resolution, initially developed to study energy transport in hot dense plasmas (9), are now commercially available.

In order to extend scientific and technological opportunities, a bright source of tunable, partially coherent, XUV radiation is needed. Coherence, in the limited sense used here, refers to the ability to form interference patterns when wave fronts are separated and recombined. Partially coherent radiation is capable of producing clear interference patterns (fringes), but only within limited transverse or longitudinal displacement (10). The longitudinal displacement within which fringes can be formed is called the coherence length  $\ell_c$  (11), which is given by the wavelength  $\lambda$  times the number of waves of coherence  $\lambda/\Delta\lambda$  (spectral purity):  $\ell_c = \lambda^2/\Delta\lambda$ .

For experiments that utilize phase-sensitive techniques, such as x-ray interferometry and x-ray microholography, a radiation field with full spatial coherence and several micrometers ( $\mu\text{m}$ ) of longitudinal coherence is often satisfactory.

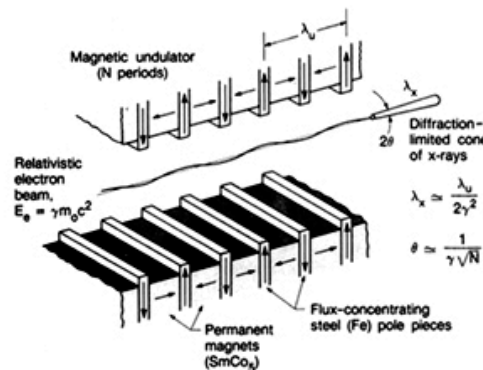


Fig. 1. Partially coherent x-rays are produced when a thin, pencil-like beam of relativistic electrons traverses a periodic magnetic structure. The radiation is relativistically contracted to short wavelengths and condensed to a narrow forward cone.



# November 1985 ALS workshop



Don Stevens  
Judy Bostok  
Klaus Halbacht  
Martha Krebs  
Yuan Lee



# Workshop Report December 1985



PUB-5154  
December 1985

Report of the Workshop on an  
Advanced Soft X-Ray and  
Ultraviolet Synchrotron Source:  
Applications to Science and Technology  
November 13-15, 1985  
Berkeley, California

Lawrence Berkeley Laboratory  
University of California  
Berkeley, California 94720

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098



# ALS is in the budget

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THE NEW YORK TIMES, WEDNESDAY, FEBRUARY 5, 1986

## State of the Union: Reagan Reports to the Nation

### Transcript of President's Speech to Congress on State of Union

Following is a transcript of President Reagan's State of the Union Message to Congress last night, as recorded by The New York Times:

Thank you very much, Mr. Speaker. Mr. President, distinguished members of the Congress, honored guests, and fellow citizens, thank you for allowing me to delay my address until this evening. We paused together to mourn and honor the value of our seven Challenger heroes. And I hope that we are now ready to do what they would want us to do — go forward America, and reach for the stars. We will never forget those brave seven, but we shall go forward.

Mr. Speaker, before I begin my prepared remarks, may I point out that tonight marks the 10th and last State of the Union Message that you've presided over. On behalf of the American people, I want to salute you for your service to Congress and country. Here's to you, Tip.

I have come to realize with you the progress of our nation, to speak of unfinished work and to set our sights on the future. I am pleased to report the state of our union is stronger than a year ago, and growing stronger each day. Tonight, we look out on a rising America — firm of heart, united in spirit, powerful in pride and patriotism. America is on the move.

#### 'Land of Broken Dreams'

But, it wasn't long ago that we looked out on a different land — locked factory gates, long gasoline lines, intolerable prices and interest rates turning the greatest country on earth into a land of broken dreams. Government growing beyond our consent had become a lumbering giant, hamstringing the gates of opportunity, threatening to crush the very roots of our freedom.

What brought America back? The American people brought us back — with quiet courage and quiet resolve, with undying faith that in this nation under God the future will be ours, for the future belongs to the free.

Tonight the American people deserve our thanks — for 17 straight months of economic growth; for sunrise firms and modernized industries creating 9 million new jobs in three years; interest rates cut in half, inflation falling over 100 to under 4; a river of good will in voluntary action.

And despite all modern world, musty remains a society, guardians for the future must be the c we say tonight: be at the heart of Nation as 'E'

more secure world. And we speak about the necessity for actions to steel us for the challenges of growth, trade, and security in the next decade and the year 2000. And we will do it — not by breaking faith with bedrock principles, but by breaking free from failed policies.

Let us begin where storm clouds loom darkest — right here in Washington, D.C. This week, I will send you our detailed proposals; tonight, let us speak of our responsibility to redefine government's role: not to control, not to command, not to constrain; but to help in times of need, above all, to create a ladder of opportunity to full employment — so that all Americans can climb toward economic power and justice on their own.

But, we cannot win the race to the future shackled to a system that can't even pass a Federal budget. We cannot win that race held back by horse-and-buggy programs that waste tax dollars and squander human potential. We cannot win that race if we are swamped in a sea of red ink.

#### 'Budget System Is Broken'

Now, Mr. Speaker, you know, I know, the American people know — the Federal budget system is broken; it doesn't work. Before we leave this city, let's you and I work together to fix it — so that then we can finally give the American people a balanced budget.

Members of Congress, passage of Gramm-Rudman-Hollings gives us an historic opportunity to achieve what has eluded our national leadership for decades — forcing the Federal Government to live within its means.

Your schedule now requires that the budget resolution be passed by April 15th — the very day America's families have to foot the bill for the budgets that you produce.

How often we read of a husband and wife — both working, struggling from paycheck to paycheck to raise a family, meet a mortgage, pay their taxes and bills. And yet, some in Congress say taxes must be raised. Well, I'm sorry, they're asking the wrong people to tax them that badly. It's time we



**CHEERING THE CHIEF:** President Reagan being applauded by Vice President Bush and Speaker Thomas P. O'Neill Jr. before speech.

Give me the authority to veto waste, and I'll take the responsibility. I'll make the cuts, I'll take the heat. This authority would not give me any monopoly power but simply pre-

security. But, as I have said before, the most powerful force we can enlist against the Federal deficit is an ever-expanding American economy, untaxed and free.

against another, one industry against another, one community against another, and that raises prices for us all. If the United States can trade with other nations on a level playing field, we can out-produce, out-compete, and out-sell anybody, anywhere in the world.

The constant expansion of our economy and exports requires a sound and stable dollar at home and reliable exchange rates around the world. We must never again permit wild currency swings to cripple our farmers and other exporters. Farmers, in particular, have suffered from past, unwise government policies; they must not be abandoned with problems they did not create and cannot control. We've begun coordinating economic and monetary policy among our major trading partners. But there's more to do, and tonight I am directing Treasury Secretary Jim Baker to determine if the nations of the world should convene to discuss the role and relationship of our currencies.

Confident in our future, and secure in our values, Americans are striding forward to embrace the future. We see it not only in our recovery, but in three straight years of falling crime rates, as families and communities band together to fight pornography, drugs, and lawlessness, and to give back to their children the safe, and yes, innocent childhoods they deserve.

#### Schools and Families

We see it in the resurgence in education, the rising S.A.T. scores for three years — last year's increase the highest since 1963. It wasn't government and Washington lobbyists that hurried education ahead — it was the American people who, in reaching for excellence, knew to reach back to basics. We must continue the advance by supporting discipline in our schools, teachers that give parents freedom of choice, and we must give back to our children their last right to acknowledge God in their classrooms.

We are a nation of idealists, yet today there is a wound in our national conscience; America will never be whole as long as the right to life is denied by our creator is denied to

a land that is free and just in a world at peace. It is my hope that our future summit in Geneva and Mr. Gorbachev's upcoming visit to America can lead to a more stable relationship. Surely no people on earth hate war or love peace more than we Americans.

But we cannot stroll into the future with childlike faith. Our differences with a system that openly prelates, and practices, an alleged right to command people's lives and to export its ideology by force are deep and abiding.

#### Realism in Diplomacy

Logic and history compel us to accept that our relationship be guided by realism — rock-hard, clear-eyed, steady and sure. Our negotiators in Geneva have proposed a radical cut in offensive forces by each side, with no cheating. They have made clear that Soviet compliance with the letter and spirit of agreements is essential. If the Soviet Government wants an agreement that truly reduces nuclear arms, there will be such an agreement.

But arms control is no substitute for peace. We know that peace follows in freedom's path and conflicts erupt when the will of the people is denied. We must prepare for peace not only by reducing weapons, but by bolstering prosperity, liberty, and democracy wherever we can.

We advance the promise of opportunity every time we speak out on behalf of lower tax rates, freer markets, sound currencies around the world. We strengthen the family of freedom every time we work with allies and come to the aid of friends under siege. And we can enlarge the family of free nations if we will defend the unalienable rights of all God's children to follow their dreams.

To those imprisoned in regimes held captive, to those beaten for daring to fight for freedom and democracy — for their right to worship, to speak, to live and to prosper in the family of free nations — we say to you tonight: you are not alone. Freedom fighters, America will support you with moral and material assistance your right not just to fight and die for freedom, but to fight and win freedom — to win freedom in Afghanistan, in Rhodesia, and in Nicaragua.

nat moral challenge for world. Surely, no issue stant for peace in our see, for the security of s — than to achieve Nicaragua and to pro- democratic neigh-

as I will be asking Com- means to do what must a great and good cause, the inspiration for a Commission on Cen-

The American dream is a song of hope that rings through the night winter air. Vivid, tender music that warms our hearts when the least among us aspire to the greatest things to venture a daring enterprise; to unearth new beauty in music, literature, and art; to discover a new universe inside a tiny silicon chip or a single human cell.

# LBL's World Class Accelerator Team (AFRD) Designs a State-Of-The-Art Low Emittance Machine



## Director's Technical Review of the Advanced Light Source

February 18-19, 1986 February 1986

### Advanced Light Source Overview

Klaus H. Berkner

### Photon Performance of ALS

Kwang-Je Kim

### Storage Ring Design and Performance

Max Cornacchia

### Advanced Light Source Injection System

Michael S. Zisman

### ALS Vacuum System

Kurt Kennedy

### Study of Chamber Impedance

Glen Lambertson

### Magnet System Design and Performance

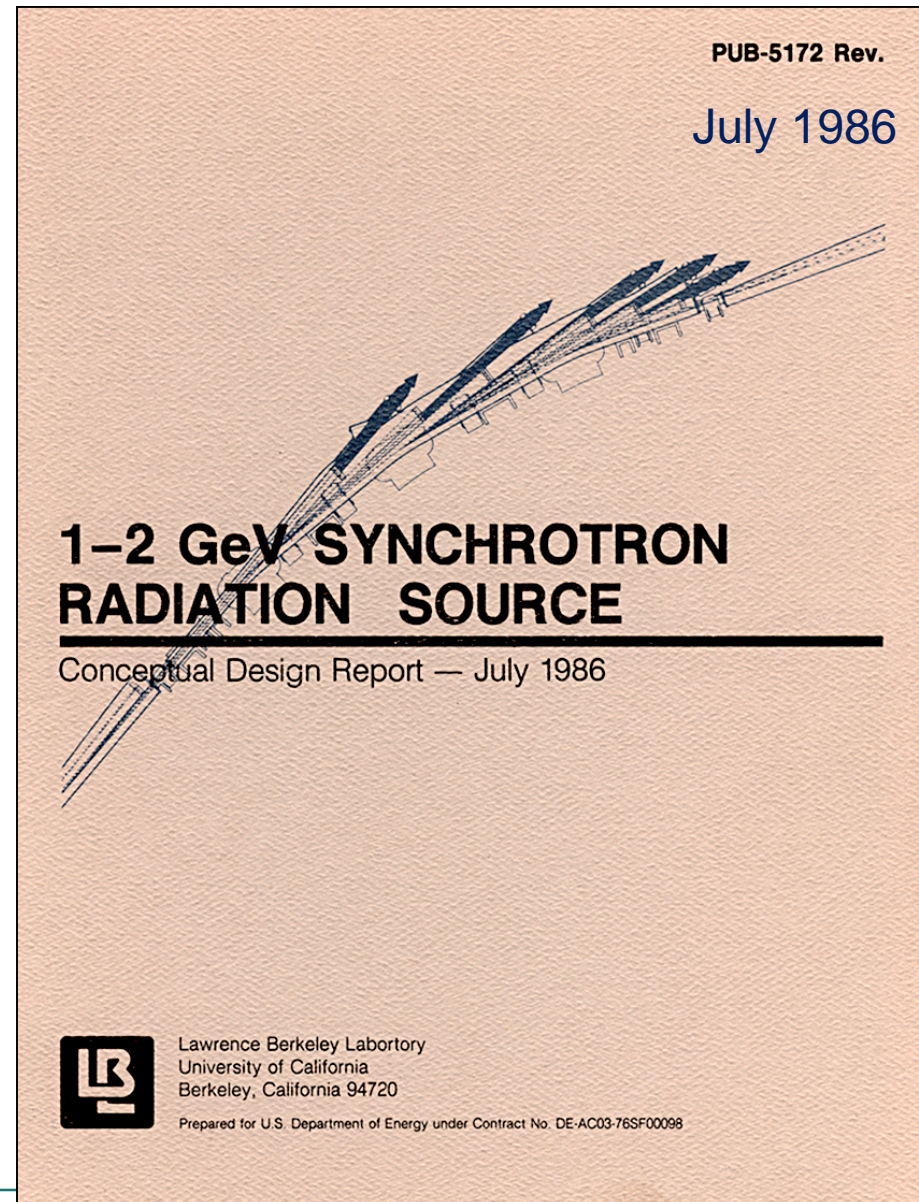
R.T. Avery

### Control, Feedback & Power Systems

Henry Lancaster

### ALS Program and R&D Issues

Jay Marx



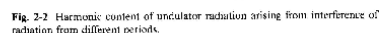




**Fig. 2-1.** Schematic of a periodic magnet structure (an undulator) of period  $\lambda_u$  and with a number of periods,  $N$ . The oscillations of the electron beam passing through the structure produce ultraviolet and soft x-ray radiation (photons) of high spectral brightness and high coherent power.

where  $g$  is the full magnetic gap [Halbach, 1983].

The radiation spectrum from a bending magnet is smooth, centered around the critical frequency  $\omega_c$ . Wigglers can be regarded as a sequence of bending magnets of alternating polarity. Thus, its radiation characteristics are similar to those from bending magnets, apart from a  $2N$  fold enhancement of the intensity, where  $2N$  is the number of the poles. (As



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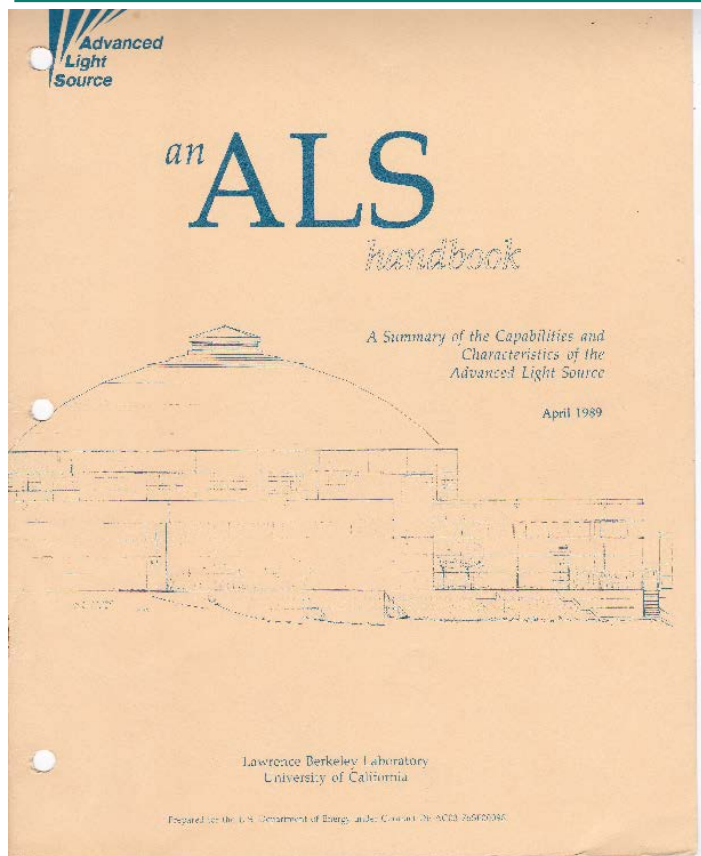
$$P_T[\text{kW}] = 0.633 E^2[\text{GeV}] B_0^2[\text{T}] L[\text{m}] I[\text{A}]$$

For bending magnets,  $B_0^2$  in the above expression must be replaced by  $2B^2$ , where  $B$  is the magnetic field in the bending magnet. The angular distribution of the radiated power is

$$\frac{d^2\rho}{d\theta d\psi} = P_2 \frac{21\gamma^2}{16\pi K} G(K)f_K(\gamma\theta, \gamma\psi), \quad (2.40)$$

[illegible]

# ALS Handbook April 1989



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and for samarium-cobalt magnets by

$$B_p = 3.33 \exp \left[ -\frac{K}{H_p} \left( 5.47 - 1.8 \frac{H_p}{K} \right) \right] \quad 0.07 < \frac{H_p}{K} < 0.7 \quad (3-13)$$

where  $\mu$  is the full magnetic gap (Hofbach, 1983). These equations apply directly to wiggle designs, where the emphasis is on achieving a high peak field. For undulators, the deflection parameter  $K$  is more important, and the optimum magnetic design differs from that of a wiggler. Although there is no known universal function for the undulator field strength, a conservative engineering design results in peak fields approximately equal to 0.95 times the values derived from Eqs. (3-12 and 3-13).

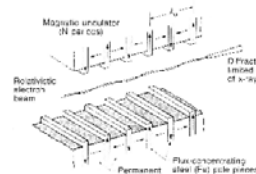


Fig. 3-1. Schematic drawing of a periodic magnet structure (an undulator) of period  $L_u$ , and with a number of periods  $N$ . The oscillations of the electron beam passing through the wiggler produce ultraviolet and soft x-ray radiation (arrows) of high spectral brightness.

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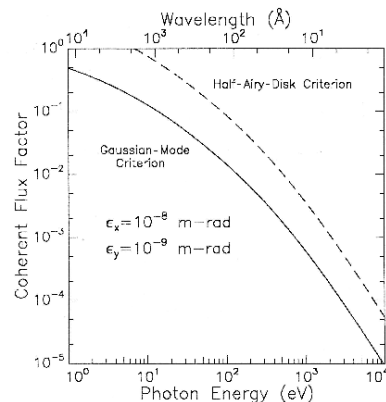
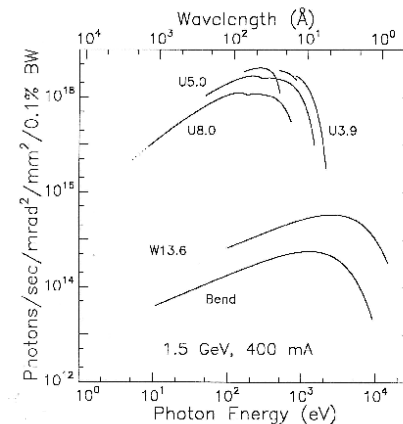


Fig. 4-4. Fraction of the flux that is transversely coherent by the single-Gaussian-mode criterion ( $\mathcal{F}/\mathcal{F}_0$  of Eq. (3-28) (solid line) and by the half-Airy disk criterion (dashed line), over the spectral range of the three undulators of Table 3-1.

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3b. Undulator U5.0.

Wavelength (Å)	SI(Å/mm)	SI(μm/mm)	SI(°/mm)	SI(°/mm)	N	IAVE(μm/mm)	AVE(μm)
0.430	0.130	0.053	0.020	0.016	98	3.00	4.8
<hr/>							
K	5.07	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	1.64E+01		
0.05	0.01	2.03E-03	7.53E-03	1.64E+01			
<hr/>							
K	1.91E+01	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	0.01		
1	4.77E+01	1.34E+03	1.34E+03	1.34E+03	1.34E+03		
5	7.78E+01	2.54E+03	5.65E+09	4.34E+10	1.06E+05		
5	2.18E+01	5.59E+01	1.23E+04	1.23E+04			
<hr/>							
K	5.07	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	1.64E+01		
0.50	0.1	2.03E-03	7.53E-03	1.64E+01			
<hr/>							
K	1.91E+01	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	0.01		
1	4.77E+01	1.34E+03	1.34E+03	1.34E+03	1.34E+03		
5	7.78E+01	2.54E+03	5.65E+09	4.34E+10	1.06E+05		
5	2.18E+01	5.59E+01	1.23E+04	1.23E+04			
<hr/>							
K	5.07	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	1.64E+01		
1.20	0.28	1.84E-01	3.82E+02	5.21E+02			
<hr/>							
K	1.91E+01	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	0.01		
1	4.77E+01	1.34E+03	1.34E+03	1.34E+03	1.34E+03		
5	7.78E+01	2.54E+03	5.65E+09	4.34E+10	1.06E+05		
5	2.18E+01	5.59E+01	1.23E+04	1.23E+04			
<hr/>							
K	5.07	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	1.64E+01		
1.02	0.02	1.75E-01	1.75E+01	6.25E+01			
<hr/>							
K	1.91E+01	PTOT(W)	PDEN2(W/mm^2)	PCEN(W)	0.01		
1	4.77E+01	1.34E+03	1.34E+03	1.34E+03	1.34E+03		
5	7.78E+01	2.54E+03	5.65E+09	4.34E+10	1.06E+05		
5	2.18E+01	5.59E+01	1.23E+04	1.23E+04			

# Characteristics of Synchrotron Radiation 1989



Page 565-632, AIP Conference Proceedings 184, "Physics of Particle Accelerators,"  
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## CHARACTERISTICS OF SYNCHROTRON RADIATION

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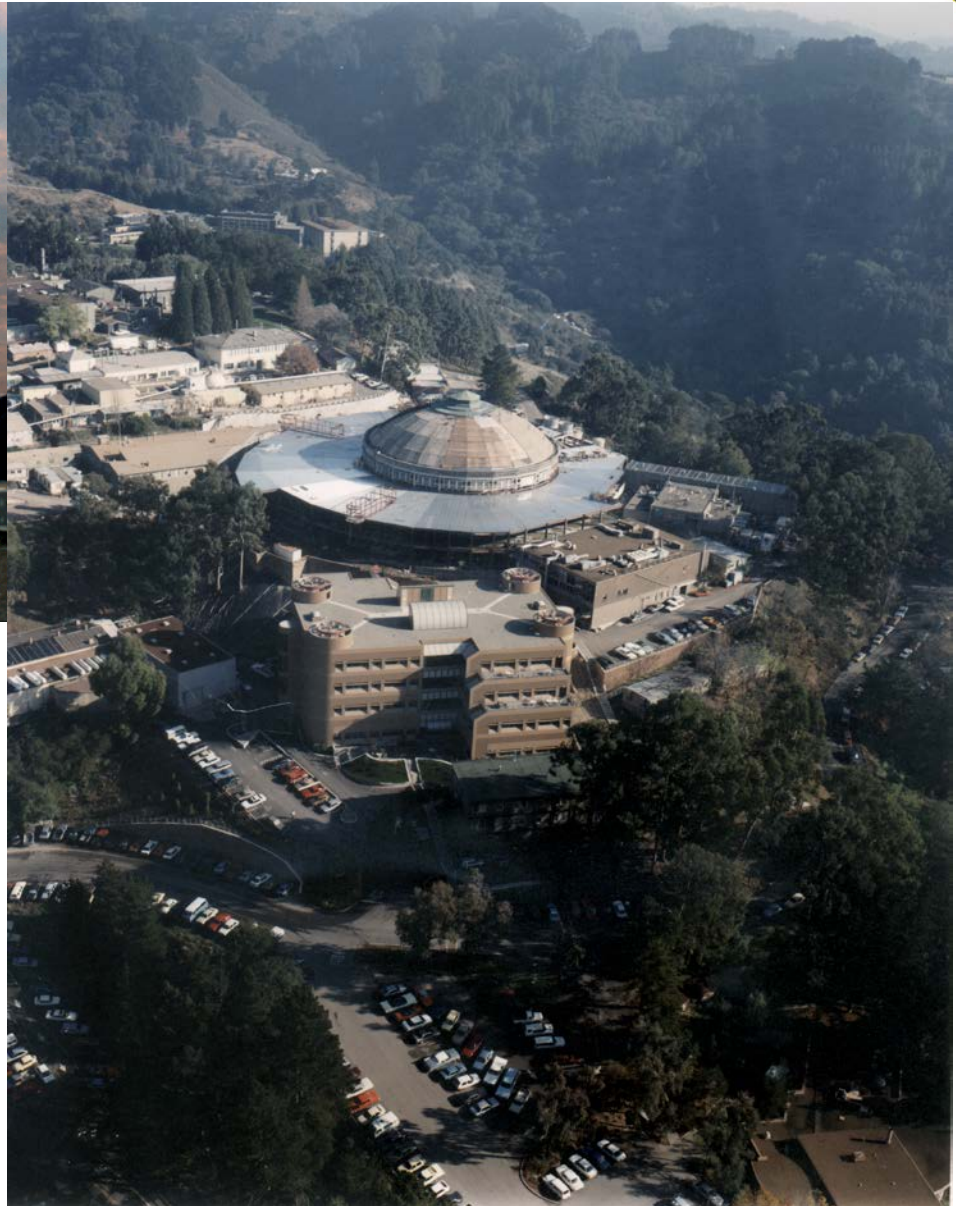
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# ALS Construction Begins, 1988



# First Light at the ALS, October 4-5 1993



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### ALS produces first light

By Lynn Yarris

The Advanced Light Source, LBL's newest, largest, and most technologically advanced accelerator, produced its first experimental light this week. During a Tuesday afternoon ceremony to mark the occasion, a phosphor-painted target glowed bright orange when it was struck by a beam of white x-ray light from bending-magnet port 10.3. Many of the people who made the moment possible watched the event on a video monitor.

The actual first light from the ALS came at 11:34 p.m. the previous night (Oct. 4), when the beamline was put through its final preparatory tests. Word of the success

Optics (CXRO), led the development of the beamline, which will serve as a fluorescent x-ray microprobe available for use by LBL groups to study material, biological, and geological samples. He opened Tuesday's ceremony by thanking the staffs of the ALS and the CXRO, as well as LBL Materials Sciences Division (MSD) Director Daniel Chemla and acting ALS scientific adviser Phil Ross, who helped obtain funding for the beamline which came from the U.S. Department of Energy's Division of Materials Science in Germantown, Md.

"We're all celebrating this day!" Thompson enthused.

Bending-magnet port 10.3 features the longest beamline

the concurrent running of independent experiments. For now, the single branch will be used by Thompson and his CXRO collaborators, Jim Underwood, Karen Chapman, Phil Batson, Ron Tackaberry, Drew Kemp, and Steve Klingler to study trace elements in materials.

The ALS x-ray microprobe is capable of simultaneously detecting and measuring the presence of elements from potassium to zinc in amounts as small as a millionth of a billionth of a gram. Its first use will be to analyze the distribution of trace elements in ceramic materials in an effort to answer the age-old mystery of why ceramics are so brittle. This experiment is a collabora-



# Best wishes to Kwang-Je on his 75<sup>th</sup> birthday

