

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

A SYNCHROTRON RADIATION SOURCE WITH ARBITRARILY ADJUSTABLE ELLIPTICAL POLARIZATION

### Permalink

<https://escholarship.org/uc/item/7bv9g4pf>

### Author

Kim, K.J.

### Publication Date

1983-08-01



# Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

## Accelerator & Fusion Research Division

RECEIVED  
LAWRENCE  
BERKELEY LABORATORY

SEP 26 1983

LIBRARY AND  
DOCUMENTS SECTION

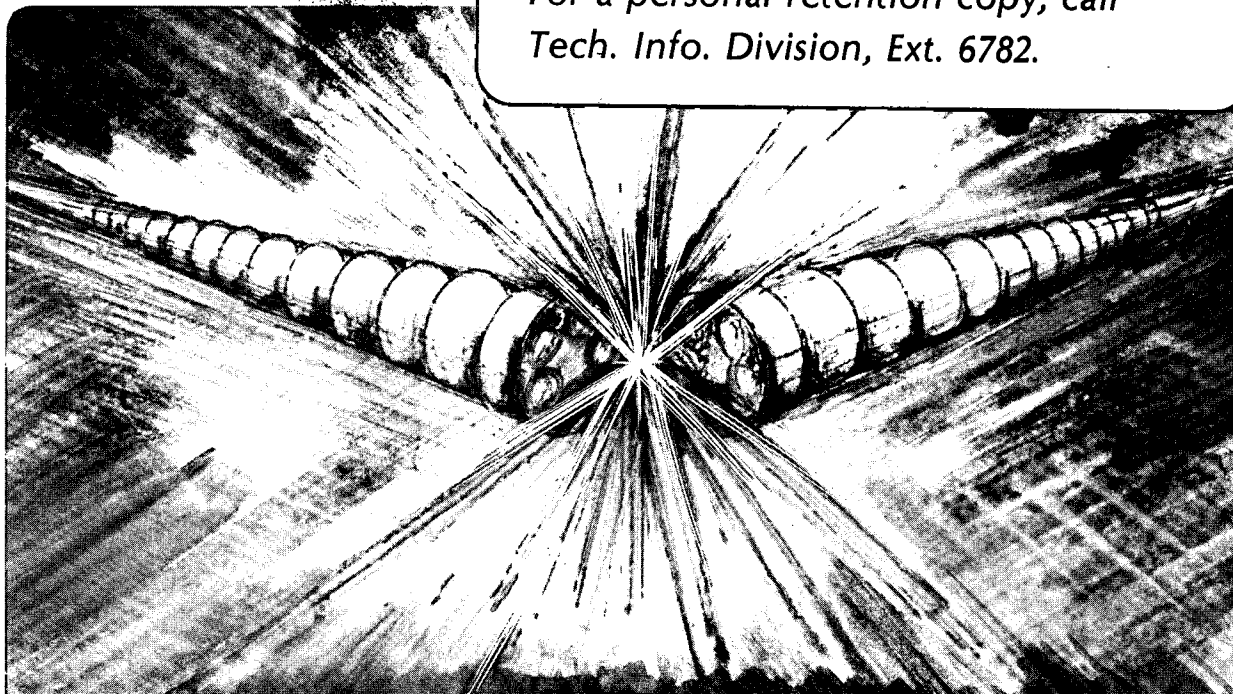
Presented at the Stanford Synchrotron Radiation  
Laboratory and Stanford Linear Accelerator Center  
Workshop on New Rings, Stanford, CA, July 27-29, 1983

A SYNCHROTRON RADIATION SOURCE WITH ARBITRARILY  
ADJUSTABLE ELLIPTICAL POLARIZATION

K.J. Kim

August 1983

**TWO-WEEK LOAN COPY**  
*This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 6782.*



LBL-16593 Summary  
c.2

## **DISCLAIMER**

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

A SYNCHROTRON RADIATION SOURCE WITH ARBITRARILY  
ADJUSTABLE ELLIPTICAL POLARIZATION

Kwang Je Kim

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

Summary

A device that can produce synchrotron radiation whose polarization is arbitrary and adjustable is proposed here. The polarization can be linear and be switched between two mutually perpendicular directions, or it can be circular and be switched between right and left circular polarizations. The system works on electron storage rings with small electron beam emittance, and can cover a wide range of photon energies.

A schematic of the proposed system is shown in Fig. 1. It consists of two identical parts, one of which is rotated  $90^\circ$  relative to the other. Each part consists of a planar N period undulator with period length  $\lambda_u$  and an additional magnet, which will be referred to as the modulator (shown in the figure as the shaded block). The modulator can be considered as a variable field single period undulator of period length  $\lambda_M$ .

An electron passing through the system will give rise to a radiation with the following polarization vector

$$\underline{\epsilon} = \frac{1}{\sqrt{2}} (x + e^{i\alpha} y) \quad . \quad (1)$$

Here  $\alpha$  is given by

$$\alpha = \frac{\pi}{\lambda_Y} \left( N\lambda_u (1 + K^2/2) + \lambda_M(1 + K_M^2/2) + D \right), \quad (2)$$

where  $\lambda$  is the wave length of the observed photons,  $D = D_1 + D_2$ , and  $K$  and  $K_M$  are the deflection parameters of the undulator and the modulator respectively. The deflection parameter is defined to be 0.934 times the peak magnetic field in tesla times the undulator period in cm. The radiation is peaked at

$$\lambda = \lambda_u (1 + K^2/2) / (2\gamma^2 n) \quad , \quad (3)$$

where  $n$  is a positive integer. In this note, only the first harmonic  $n = 1$  is considered.

If the two undulators are placed parallel rather than perpendicular to each other, the polarization will be linear. However, the radiation intensity will have an interference pattern due to the factor  $|1 + e^{i\alpha}|^2$  superimposed on the undulator spectrum. The system then becomes identical to the optical klystron.

Equation (1) corresponds to the general case of elliptically polarized light. As one varies  $\alpha$  between 0 and  $2\pi$ , the polarization ellipse changes as shown in Fig. 2. Therefore, one can obtain any desired polarization by adjusting  $\alpha$ .

The phase  $\alpha$  can be changed by either of the following two methods: First, the distance  $D$  can be changed mechanically. The advantage of this method is that the radiation intensity remains constant during the modulation of the polarization. However, this method cannot exceed a frequency of polarization change much greater than 1 Hz. Alternatively, the magnetic field of the modulator can be changed. This can be done at a rate of 1 kHz

or more. However, the radiation intensity changes as  $\alpha$  changes. If the distance between the first undulator and the modulator  $D_1$  is chosen properly, the relative intensity variation  $\Delta I/I$  can be minimized and is given by

$$\frac{\Delta I}{I} \approx \frac{1}{N^2 K^2} \frac{\lambda_u}{\lambda_M} (1 + K_M^2/2) . \quad (4)$$

The variation of  $\alpha$  by  $\pi$  is assumed here.

The angular spread of the electron beam limits the degree of the obtainable polarization  $P$ . It can be shown that

$$1 - P = \frac{1}{2} \left( \alpha_0 \frac{\sigma_\lambda}{\lambda} \right)^2 + \left( 2\pi\eta \frac{\gamma^2 \sigma_\theta^2}{1 + K^2/2} \right)^2 \quad (5)$$

Here  $\alpha_0$  is the phase of the ideal case given by Eq (1),  $\sigma_\theta$  is the  $1 - \sigma$  value of the electron angle with respect to the z-axis and

$$\frac{\sigma_\lambda}{\lambda} = \sqrt{\left( \frac{\Delta\lambda}{\lambda} \right)^2 + 4 \left( \frac{\sigma_\gamma}{\gamma} \right)^2}$$

$$\eta = N + \frac{\lambda_M + D}{\lambda_u} .$$

In the above,  $\Delta\lambda$  is the monochromator band-pass and  $\sigma_\gamma$  is the  $1 - \sigma$  electron energy spread.

(1 - P) in Eq. (5) gives merely the fraction of the unpolarized part of the total flux, and has nothing to do with the shape of the polarization. If  $P = 0.8$ , for example, the polarization is only 80%. However, the polarization ellipse can be of any shape. In particular it can be exactly circular.

Eq. (5) requires the angular spread  $\sigma_{\theta}$  to be small in order to have the large N value. Recall that N needs to be large in the method of the magnetic modulation to minimize the intensity variation given by Eq. (4).

Table I gives parameters of two example systems, the first based on the VUV ring at NSLS and the second a future ring such as those proposed by LBL and SSRL. The angular spread of  $\sigma_{\theta} = 0.02$  mrad is consistent with the emittance of these rings if a special high- $\beta$  straight section is introduced. The total flux on samples is estimated to be  $\geq 10^{12}$  photons per second for both examples. This estimate assumes a combined optical efficiency of  $\leq 1\%$  due to reflection losses from mirrors and gratings.

In the examples, the polarization is assumed to be modulated magnetically. In the case of the mechanical modulation, the parameters are similar but the intensity variation will be zero. The modulation distance  $\Delta D$  is 10 cm for the first and 3 cm for the second example. These examples show that the proposed system is potentially an extremely versatile source of polarized radiations.

#### Acknowledgements

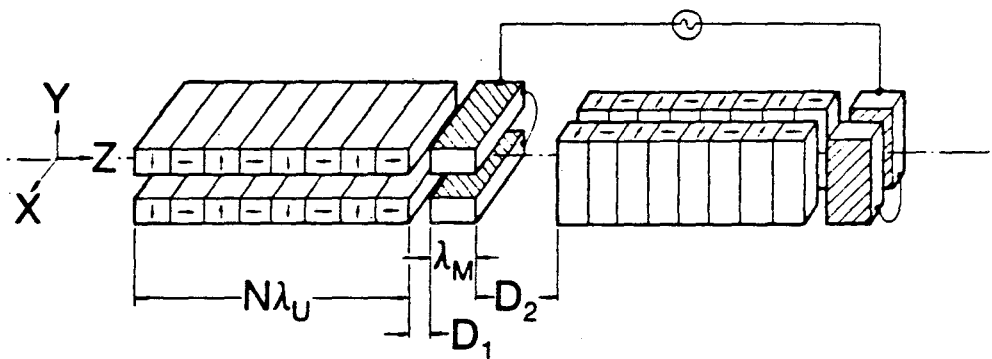
I thank H. Winick and other participants of the workshop for their enthusiasm and discussions. I also thank T. Elioff, K. Halbach, M. Maestre, R. Sah, and I. Tinoco for many useful discussions and encouragement. This work was supported by the Director of the Office of Energy Research, Office of High Energy and Nuclear Physics, Division of Nuclear Science under Contract DE-AC03-76SF00098.

Table I. Parameters of Example Systems

	Ring	
	VUV (NSLS)	Future
E (GeV)	0.75	1.3
$\sigma_{\theta}$ (mrad)	$9.0 \times 10^{-2}$	$2 \times 10^{-2}$
K	$\sqrt{2}$	1
N	5	30
$\lambda_U$ (cm)	10	4
$\lambda_1$ (Å)	470	47
$\lambda_M$ (cm)	10	4
$B_{M1}$ (kG) <sup>a</sup>	2.14	2.68
$B_{M2}$ (kG) <sup>a</sup>	2.62	4.23
$\Delta I/I$ (%)	4	0.17
$\sigma_{\lambda}/\lambda$ (%)	0.4	0.14
P (%)	86	84

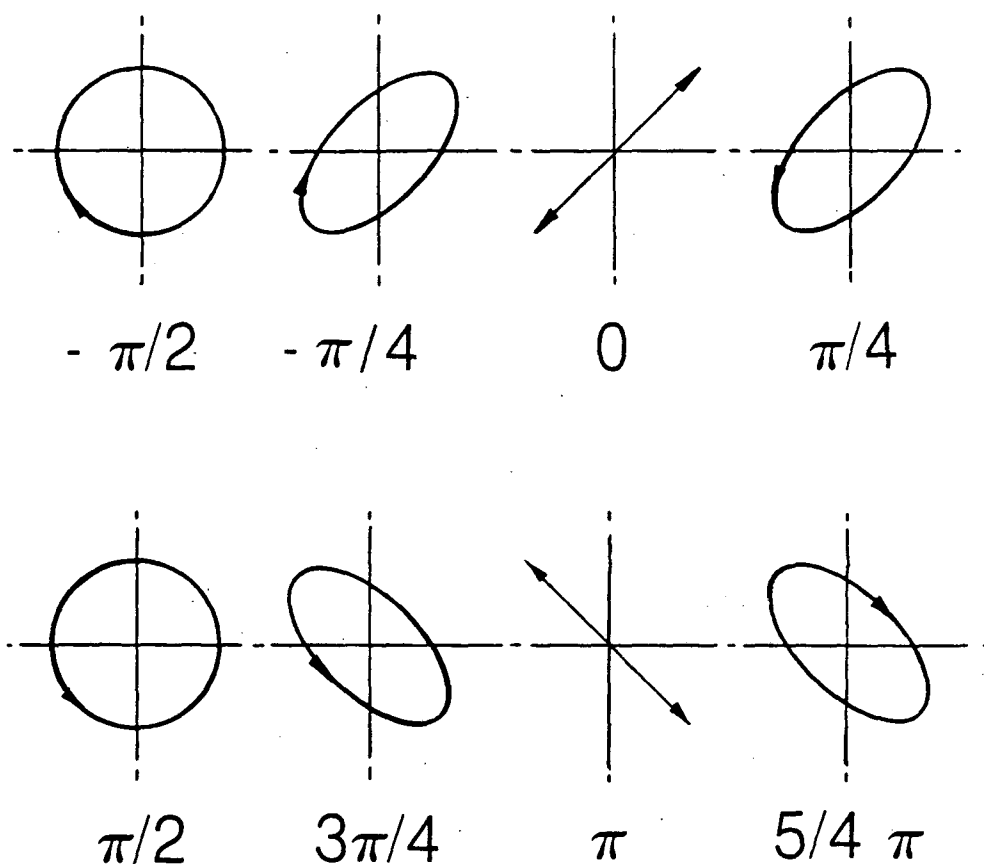
<sup>a</sup> $B_{M1}$  = lower value of modulator magnetic field;  $B_{M2}$  = upper value of modulator magnetic field.





XBL 838-3124

Fig. 1. Schematic of the proposed system.



XBL 838-3125

Fig. 2. Evolution of the polarization ellipse as  $\alpha$  increases from  $-\pi/2$  to  $5/4\pi$ . The  $\alpha$  values are shown below the ellipses.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

TECHNICAL INFORMATION DEPARTMENT  
LAWRENCE BERKELEY LABORATORY  
UNIVERSITY OF CALIFORNIA  
BERKELEY, CALIFORNIA 94720