BNL- 64646
Informal Report

**Measurements of Emittance Growth Through the Achromatic Bend
at the BNL Accelerator Test Facility**

X.J. Wang and D. Kehne

July 1997

National Synchrotron Light Source
Brookhaven National Laboratory,
Upton, NY 11973 USA

MASTER

Work performed under the auspices of the U.S. Department of Energy,
under contract DE-AC02-76CH00016

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Measurements of Emittance Growth through the Achromatic Bend at the BNL Accelerator Test Facility

X.J. Wang, Brookhaven National Laboratory
and
D. Kehne, Thomas Jefferson National Accelerator Facility
6/18/96

Measurements of emittance growth in a high peak current beam as it passes through an achromatic double bend are summarized. Experiments were performed using the ATF at Brookhaven National Laboratory by X.J. Wang and D. Kehne as a collaboration resulting from the proposal attached at the end of the document.

The ATF consists off an RF gun (1 MeV), two sections of linac(40-75 MeV), a diagnostic section immediately following the linac, a 20° bend magnet, a variable aperture slit at a high dispersion point, 5 quadrupoles, then another 20° bend followed by another diagnostic section. The TRANSPORT deck describing the region from the end of the linac to the end of the diagnostic line following the achromatic bends is attached to the end of this document. Printouts of the control screens are also attached.

Emittance growth due to CSCF

The growth in emittance due to centrifugal space charge forces (CSCF) can be calculated using the equation [1]

$$\Delta \varepsilon_n^{CSCF} = 0.38 N \alpha^2 \frac{I_p}{I_A} \ln \left(\frac{h}{4 \sigma_x} \right) \frac{2 \sigma_x^2}{3 \sigma_z}$$

where N is the number of bends, α is the bend angle, I_p is the peak current, I_A is the Alfven current, σ_x is the rms beam size and σ_z is the rms bunch length. For $N=2$, $\alpha = 20^\circ$, $h = 0.025$, and $I_p \approx Q/(2.5 \sigma_t)$, this can be reduced to

$$\Delta \varepsilon_n^{CSCF} = 4.83 \times 10^{-15} Q \left(\frac{\sigma_x}{\sigma_t} \right)^2 \ln \left(\frac{6.25 \times 10^{-3}}{\sigma_x} \right)$$

where Q is the charge per bunch and σ_t is the rms bunch length in seconds.

Emittance growth due to CSR

The growth in emittance due to coherent synchrotron radiation(CSR) [2] can be calculated using the equation [3]

$$\Delta\epsilon_n^{CSR} = 0.5\alpha^2 N \frac{I_p}{I_A} \sigma_x \left(\frac{R}{\sigma_z} \right)^{1/3}$$

where R is the bend radius and the other parameters are as for the previous equations. For R = 1.146 meters, $\alpha = 20^\circ$, N=2, and $I_p \approx Q/(2.5\sigma_t)$, this can be altered to

$$\Delta\epsilon_n^{CSR} = 4.48 \times 10^{-9} \left(Q \frac{\sigma_x}{\sigma_t^{4/3}} \right) ..$$

Selection of Operating Parameters

A summary of the beam parameters is given in Table 1. Charge per bunch is changed by varying the phase of the RF gun phase. An approximate plot of charge per bunch vs bunch length is shown in Fig. 1. Since these two are dependent on each other, the only adjustable independent parameter was the beam size. Beam size through the bends was adjusted using a quadrupole prior to the bend and measured using a viewer at the bend entrance. The initial measurements were done with a beam with $\sigma_x \approx 0.4$ mm through the bend. The final two measurements were done with beam sizes of $\sigma_x \approx 0.8$ and 1.1 mm respectively. In the final measurement, the beam size through the second bend was $\sigma_x \approx 1.5$ mm. The beam size at the second bend was not measured for the first two cases(an oversight).

Plots of change in emittance for CSCF and CSR using the above equations are plotted in Fig. 2. The emittance is relatively insensitive to charge per bunch and bunch length (this is because the two are not independent). A charge per bunch of 200 pC was chosen for stability reasons. This did seem to drift from 200-250 pC, however, during the course of the measurements.

A plot of the longitudinal bunch profile is shown in Fig. 3a. Measurements were taken at the beginning and end of the experiments. At the end of the sequence of experiments, the bunch length seems to have increased. Fitting the measurements to a Gaussian gives $\sigma_x \approx 1$ mm and ≈ 1.5 mm respectively. Also, a low density tail was present in both cases.

Experimental Plan

The following sequence was followed during the measurements.

1. The linac was set to the desired energy (45 MeV) and crested.
2. Setup desired bunch length and charge per bunch

- a. Bunch charge set by varying the phase of the RF gun. Thus, bunch length and charge per bunch are not independent of each other
3. Measure bunch length
 - a. Place linac 30° off crest
 - b. Measure amplitude of stripline signal after high energy slit as a function of RF Amplitude. Bunch length can be correlated from that data.
4. Measure emittance prior to achromatic bends
5. Emittance measurement method
 - a. Adjust upstream quad (with all intermediate quads zero) so that the beam intensity is maximized (using false color CCD images) [Note: minimum spot size does not imply waist]
 - b. Measure beam size at this viewer and another separated by a drift L from the first (2 profile method)
 - c. Estimate emittance using the following equation

$$\epsilon_x = \frac{\beta\gamma D_0 \sqrt{D_1^2 - D_0^2}}{16L}$$

where D_0 is the full(edge to edge) beam diameter at the minimum spot, D_1 is the full beam diameter at the other viewer, L is the drift between the two viewers, and $\beta\gamma$ is the usual relativistic term.

5. Setup beam through achromatic bends with small spot size and zero dispersion after 2nd bend.
6. Measure emittance after achromatic bends
 - a. Adjust last quad BEFORE second bend to minimize spot at 1st viewer after bend(this gives final tweak on zeroing dispersion)
 - b. Adjust quad after bend to minimize spot at second viewer
 - c. Measure spot sizes at the two viewers
 - d. Estimate rms normalized emittance using the following equation

$$\epsilon_x = \frac{\beta\gamma D_0 \sqrt{D_1^2 - D_0^2}}{16L}$$

where D_0 is the full(edge to edge) beam diameter at the minimum spot, D_1 is the full beam diameter at the other viewer, L is the drift between the two viewers, and $\beta\gamma$ is the usual relativistic term.

Discussion

Table 2 and Fig. 3b summarize the experimentally measured emittance values. The agreement between simulation and the theory seems good. However, as can be seen from the image data in Figs. 4, 5, and 6, there is considerable question as to what is causing the emittance growth. The beam "waist" during the second two measurements are tilted significantly and it is not clear what caused this. A list of potential problems is given below.

Potential problems:

1. Emittance method
 - a. Is minimum spot size necessarily a waist?
 - b. Edge-to edge size = 4σ as assumed?
2. What causes tilt in x-y space?
 - a. Skewed field?
 - b. Wake fields?
3. What are the effects of wakefields?
4. Was dispersion adequately suppressed?

Table 1. Summary of beam parameters

Parameter	Value	How Measured
Energy	45 MeV	Dispersion slit
Energy spread	<0.5%	Dispersion slit
Charge per bunch (Q)	200-250 pC	FC
Bunch length (σ_t)	1-1.5 pC	Inducing ΔE using linac phase and calculate σ_t from induced energy spread.
ϵ_x (Norm, rms) (after linac, before bend)	1.5 mm-mrad	2 viewers
σ_x	0.4 mm, 0.8 mm, 1.1 mm, 1.5 mm	viewer

Fig. 1. Charge per bunch plotted vs rms bunch length.

Fig. 2. Expected emittance change for various beam sizes (from the experiment) plotted versus charge per bunch.

Fig. 3a. Measured longitudinal profiles taken before and after the emittance measurements.

Table 2. Summary of experimental results and comparison with theory.

σ_x [mm]	σ_t [ps]	Q [pC]	ϵ_{xi} [mm-mrad] Measured before bend	ϵ_x [mm-mrad] Measured after bend	$(\epsilon_{xi}^2 + \Delta\epsilon^2_{CSR} + \Delta\epsilon^2_{CSCF})^{1/2}$ (theory)
0.4	1.5	200	1.5	2.3	2.6
0.8	1.5	200	1.5	3.6*	4.5
1.1/1.5	1.5	200	1.5	6.8*	6-8

*Beam significantly distorted at waist

Fig. 3b. Plots of theoretical emittance and measured emittance versus beam size. The value of initial measured emittance is shown as a reference.

References

- [1] B. E. Carlsten and T. O. Raubenheimer, Phys. Rev. E 51, 1453 (1995).
- [2] Y. S. Derbenev, J. Rossbach, E. L. Saldin, and V. D. Shiltsev, "Microbunch Radiative Tail-Head Interaction", DESY preprint, 1995 (unpublished).
- [3] National Synchrotron Light Source Meeting Notes, "Consideration of Beam-Induced Fields in Bends -- CSCF and CSR Experiments and Theory", E. Johnson, recorder, 23-24 October 1995.

(a)

(b)

©

Fig. 4. (a) Emittance measurement before the achromatic bends performed at the beginning of the experiments (b) Emittance measurement before the achromatic bends performed at the end of the experiments. The drift between the two images for (a) and (b) is 1.25 meters. © Emittance measurement taken after the achromatic bend for the case of the horizontal edge-to-edge beam size at the 1st bend being 1.78 mm. The drift between the two images is 3.3 meters.

(a)

(b)

Fig. 5. (a) This is the beam image immediately prior to the 1st dipole after an upstream quad was adjusted to expand the beam horizontally. (b) Emittance measurement data taken after the achromatic bends. The drift length between the two viewers is 3.3 meters. Note that the beam is tilted at the waist.

B5z_
Horizontal Edge-to-edge
beam size=4.54 mm

(a)

F3z_2
Horizontal Edge-to-edge
beam size = 5.9 mm

(b)

IB_3(waist)
Horizontal Edge-to-edge
beam size=1.547 mm

I2_3
Horizontal . Edge-to-edge
beam size = 3.3 mm

©

Fig. 6. Data taken for a beam that has been expanded even more than that shown in Fig. 5. (a) The beam at the entrance to the first dipole (b) The beam at the entrance to the 2nd dipole. © Emittance data taken after the 2nd bend magnet. The drift between images is 3.3 meters.

	ATP IPBL -- OPTICS & DIAGNOSTICS	Laser direction	TOOLS	FACILITY OVERVIEW	EXIT
--	---	-----------------	--------------	--------------------------	-------------

"IFEL and EMITTANCE OPTICS"

0
13. 12.;
13.0 3.0 ; (PRINT BEAM PARAMES)
13.0 6.0 ; (PRINT R1)
16.0 "GAP " 5. 15.0 ;
-16.0 "CORR" 12. 6.0 ; (RADIUS OF CURV OF ENTRANCE FACE)
-16.0 "CORR" 13. 6.0 ; (RADIUS OF CURV OF EXIT FACE)
15. "XYMM" 1. "MM " 0.1 ; (X,Y IN MM)
-PLOT,L,S11,S22,S21,S33,S44,S43,R16;
1.0 0.35 0.162 0.35 0.16 0.30 0.5 0.0450 "BEAM" ;
-17.0 "SEC";
3.0 0.5472;
5.00 "HQ7" 0.10 0.00 10.00 ;
3.0 0.256;
5.0B "HQ8" 0.10 0.10263 10.00 ;
3.0 0.255;
5.0C "HQ9" 0.10 -0.12004 10.00 ;
3.0 0.2398;(to the screen of BPM 5)
3.0 0.3026;(to the dipole entrance face)
20. 180.; (BEND LEFT)
2.0 0.0 ;
4.0 'FD1' 0.400 1.30988 0.000; (HD1,first bend of achromat)
2.0 0.0 ;
20. -180.;
3.0 0.6705 "FP1"; (TO THE CENTER OF THE FPOP1)
3.0 0.389;
5.00 0.10 0.17180 10.00 "FQ1";
3.0 0.1925 "HES"; (TO THE CENTER OF THE HIGH ENERGY SLIT)
3.0 1.00;
3.0 0.8075;
5.02 0.10 -0.08231 10.00 "FQ2";
3.0 0.1614 "FP2"; (TO THE FPOP2 CENTER)
3.0 1.00;
3.0 0.6654;
5.03 0.05 0.11321 10.00 "FQ3";
5.03 0.05 0.11321 10.00 "FQ3";
3.0 1.1524; (TO THE UPSTREAM EDGE OF D2)
3.0 .9475;
5.04 0.10 -0.08257 10.00 "FQ4";
3.0 0.50;
3.0 1.00;
3.0 0.4989;
5.0D 0.10 0.16360 10.00 "FQ5";
3.0 0.4929 "FP3"; (TO THE CENTER OF FPOP3)
3.0 0.5445; (TO THE UP EDGE OF D3)
20. 0.0;
2.0 0.0 ;
4.0 'FD4' 0.400 1.30988 0.000; (FD3, ID1)
2.0 0.0 ;
20. -0.;
10.0 -1. 6. 0. 0.001 'DX2' ; (KILL THE DISPERSION)
10.0 -2. 6. 0. 0.001 'DT2' ;
3.0 0.5622;
5.00 0.076 -0.30918 10.0 "IQ1";
3.00 0.3716;
5.0 0.076 0.394499 10.0 "IQ2";
3.0 0.547724; (to the Ipop1)
10.0 2. 1. 0. 0.001 'F21';
10.0 4. 3. 0. 0.001 'F21'; (DOUBLE WAIST)

3.0 0.69308;
5.00 0.10 -0.03762 10.00 "IQ2A";
3.0 0.40122;(to IPOP2)
3.0 1.7136;
5.0 0.076 0.333316 10.0 "IQ3";
3.0 0.305;
5.0 0.076 -0.314504 10.0 "IQ4";
3.0 1.1731;(to the screen of IBPM1)
3.0 0.3783;(to the edge of ID2)
20. 0. ;
2.0 0.0 ;
4.0 'ID2' 0.400 1.4554 0.000; (ID2)
2.0 0.0 ;
20. -0. ;
3.0 0.3095;
5.0 0.076 0.489679 10.0 "IQ5";
3.0 0.67615;
5.0 0.076 -0.438298 10.0 "IQ6";
3.0 0.425325;
5.0 0.076 0.390126 10.0 "IQ4";
3.0 2.54317;(to the end of i-line popup)
SENTINEL
SENTINEL

Emittance Growth and Coherent Synchrotron Radiation in Bends

A CEBAF-Proposed Experiment for Brookhaven National Laboratory's Accelerator Test Facility

11 December 1995

I. INTRODUCTION

The generic problem of emittance growth in bends due to noninertial space-charge effects and coherent synchrotron radiation has been circulating about the accelerator community for the past decade, mostly in conjunction with the prospect of producing high-brightness beams [1]. The bulk of the most recent activities have centered on calculating the associated longitudinal wakefields in an effort to determine how short a bunch can be maintained in storage rings which are designed to be sources of coherent synchrotron radiation [2]. However, the problem is also of interest in connection with the design of recirculating linear accelerators for high-brightness beams, in which the recirculation arcs can trigger emittance growth and beam degradation.

CEBAF has designed a recirculating linac to drive a high-power ultraviolet free-electron laser (UVFEL) for industrial use in exploring its applications for processing materials [3]. To keep capital costs down, the machine comprises a two-pass design in which 180° recirculation arcs return the beam to the linac twice for acceleration and twice for deceleration and energy recovery. There is limited margin for transverse emittance growth in the accelerator, and emittance growth in bends, especially the recirculation bends, is of paramount concern. We therefore have formulated a program to study the phenomenon and are seeking the means for its timely execution. We envision that an experiment on the Accelerator Test Facility to measure emittance growth and coherent synchrotron radiation in an achromatic bend would constitute a key component of the program.

II. THEORETICAL CONSIDERATIONS

Based on the dispersion relation for a rectangular toroidal chamber, one may expect coherent synchrotron radiation (CSR) to be suppressed in a curved beam pipe if

$$\xi \equiv \left(\frac{h}{\pi \sigma_z} \right)^2 \frac{w}{R} \ll 1,$$

where h and w are the chamber height and width, respectively, R is the orbit radius, and σ_z is the rms bunch length [1]. When this condition is violated, then there should be appreciable CSR in a wavelength interval [4]

$$2\pi\sigma_z \leq \lambda \leq 2h \left(\frac{h}{R} \right)^{1/2}.$$

Shielding from the conducting walls of the beam pipe is clearly the determining factor whether CSR will be operative.

The bends comprising the inner arcs of the CEBAF UVFEL are both isochronous and achromatic. In its tightest recirculation bends, nominal parameters are $h = w = 5$ cm, $R = 1$ m, and $\sigma_z = 0.5$ mm, which combine to give $\xi \sim 50$. Accordingly, there is concern about generation of CSR in these bends and its effect back on the beam [5].

In principle, an achromatic bend generates zero emittance growth in a beam bunch, even in the presence of an intrinsic energy spread. However, if an individual particle's energy changes while the bunch is transiting through the bend, then its final bend angle changes in proportion to the energy change. As pointed out in the recent work of Carlsten and Raubenheimer [6], hereafter called "CR", this causes the rms transverse emittance to grow to a maximum value which is proportional to the rms energy change of the ensemble of particles comprising the bunch. Unlike emittance growth from inertial space-charge forces, which varies inversely with the square of the beam energy, this emittance growth is due to noninertial effects and is independent of the beam energy.

CR estimate the normalized transverse emittance growth in a bunch transiting an achromatic bend for the case that the bunch length is short compared to the pipe aperture. Their result evolves from a series of approximations which ostensibly eliminates all effects except for the noninertial coulomb repulsion, or "centrifugal space-charge force" (CSCF):

$$\Delta \epsilon_n^{CSCF} \sim 0.38 N \alpha^2 \frac{I_p}{I_A} \ln \left(\frac{h}{4\sigma_x} \right) \frac{2\sigma_x \sigma_\beta}{3\sigma_z},$$

where N is the number of bending magnets in the achromat, α is the bend angle of a single magnet, I_p is the peak current, I_A is the Alfven current (17 kA), σ_x is the rms transverse beam size, and σ_β is the betatron beam size ($\sim \sigma_x$) [6,7]. This emittance growth is to be added in quadrature to the input emittance.

CSR acting on the beam bunch can also constitute an important source of emittance growth. DESY has been concerned about this effect in connection with the design of the TESLA Test Facility FEL [8]. Using the DESY calculation for the CSR-induced rms energy spread, Raubenheimer estimates the corresponding emittance growth, ignoring shielding from the pipe, to be [7]

$$\Delta \epsilon_n^{CSR} \sim 0.5 \alpha^2 \frac{I_p}{I_A} \sigma_x \left(\frac{R}{\sigma_z} \right)^{1/3},$$

provided the drift length in the bending magnets L_d significantly exceeds $L_o = 2(3R^2 \sigma_z)^{1/3}$. This adds in quadrature with the CSCF emittance growth, and it can be the predominant effect.

When applied to the first recirculation bend of the CEBAF UVFEL design, these expressions predict an emittance growth of about 50 mm-mrad, almost 90% of which is due to CSR. The normalized transverse emittance at the wiggler is required to be about 10 mm-mrad, so an emittance growth at this level would prohibit the use of two recirculation passes and force a one-pass design.

Both expressions, however, involve approximations which make their application to general situations suspect. CEBAF is currently pursuing a more complete theory based on a comprehensive solution of Maxwell's equations and the equations of particle motion that simultaneously accounts for both CSCF and CSR and also the transient buildup of the fields in the bend [9]. Possibly a more careful calculation will yield lower values for emittance growth. In any case, it is unarguable that a large value of ξ will translate into CSR generation, which in turn will cause the emittance to grow.

Thus, notwithstanding the detailed bunch dynamics through the arcs, we are led to expect some degradation of emittance through the transport lattice of the UVFEL, and the degradation could conceivably be severe. If so, there are a number of potential cures, including: transverse focusing to reduce σ_x ; bunch lengthening to increase σ_z and/or lowering the bunch charge (while keeping I_b large enough to generate high laser power); increasing the bend radius R to lower ξ ; using lossy pipe walls; and/or breaking each bend into a series of n uncorrelated achromatic bends to reduce the emittance growth by $1/n$. There is also a need to keep beam loss low throughout the machine. This introduces an additional concern about possible beam loss triggered by the electromagnetic fields in the pipe.

The potential problems in the CEBAF UVFEL introduced by noninertial space-charge effects are clearly serious enough to warrant a program of expeditious research. A complete understanding of this phenomenon and its potentially serious consequences for high-brightness beams will require an orchestrated combination of theory, simulations, and laboratory experiments like the one proposed here for ATF.

III. PROPOSED ATF EXPERIMENT

ATF generates a 70 MeV electron beam, which is sufficiently energetic to suppress inertial space-charge forces. The ATF beamline includes an achromatic bend which leads from the linear accelerator into the experimental hall and into the individual experimental beamlines. This bend consists of two 20° dipole bending magnets with intervening quadrupoles. By varying the phase of the rf gun, the bunch length in the ATF can be adjusted and made as short as about 1 psec rms, at which point the charge is about 200 pC [10]. The corresponding peak current is about 80 A. The nominal rms radius and normalized rms emittance for this beam is about 1 mm and 2 mm-mrad, respectively. The cross section of the beam pipe through the bending magnets has the form of a racetrack with nominal height and width of 26.7 mm and 48.4 mm, respectively, and the bending radius of the dipoles is 1.146 m. These values give $\xi \sim 34$, which is comparable to the value anticipated in the CEBAF UVFEL, and which means CSR should be excited in the bending magnets. CSR wavelengths between 2-8 mm are projected for the ATF achromat. For a 1 psec rms bunch length in the ATF magnets, $L_o = 0.2$ m. This is significantly shorter than the drift length in the

magnets, $L_d = 0.4$ m, so the previous expression for CSR emittance growth applies. Predictions for emittance growth in this achromat are $\Delta \epsilon_n^{CSR} = 1.8$ mm-mrad and $\Delta \epsilon_n^{CSR} = 4.5$ mm-mrad, for a cumulative emittance growth of 4.8 mm-mrad, or roughly 2.5 times larger than the input emittance.

In view of these considerations, the ATF beamline in its present configuration affords a good opportunity for a first study of the phenomena of interest. Moreover, its true limitations for beam production have yet to be established [10]. For example, it may be possible to generate an even brighter beam with input emittance as low as 1 mm-mrad, and it is probably also possible to increase the rms radius significantly above 1 mm to enhance the emittance growth. Other advantages are the on-site availability of beam diagnostics and the maturity of the facility.

CEBAF proposes to team with BNL and other participants to conduct a series of experiments in which emittance growth in the ATF achromat is measured as a function of beam parameters and correlated with observations of CSR in the dipole magnets. For a specified set of beam parameters, a typical experiment is envisioned to consist of measurements of the CSR power and spectral distribution in the bending magnets, the straight-line rms transverse emittance from the linear accelerator, the rms transverse emittance after the first dipole bend, and the rms transverse emittance at the exit of the achromat. This will allow a check on the evolution of the emittance through the line. This procedure clearly requires a high-resolution emittance diagnostic.

A fundamentally important aspect of the proposed experiment is to ascertain convincingly whether the measured CSR and emittance growth is due to the curved trajectory, or to unwanted effects, e.g., spurious wakes from nonuniformities in the vacuum chamber. Thus, the measurements are to be repeated subject to variation of beam parameters. For example, lengthening the bunch by varying the phase of the rf gun will enable passage from the regime of "full" coherent synchrotron radiation (large ξ) through suppression of this radiation (small ξ). As a second example, by using an optical attenuator in the photocathode laser's path, the charge per bunch can be altered, possibly without significant change to the bunch length. This allows a second check of the scaling of emittance growth with peak current, and also of the scaling of synchrotron-emission power with bunch charge, which for CSR should vary as the square of the number of particles in the bunch.

IV. PROGRAMMATICS

As configured, the proposed experiment should generate results and diagnostic procedures of general interest to the accelerator community, and of particular utility not only for CEBAF in regard to the UVFEL, but also for BNL in regard to its initiative to construct a storage ring for CSR generation in the Source Development Laboratory. Because it involves an existing facility and its associated installed hardware, the experiment is envisioned to be low in cost and fast in execution. Preparations in the form of machine studies have already commenced at ATF. Data is projected to be taken in late winter, nominally March 1996.

Participants are currently projected to be, but are not limited to:

From CEBAF: C. L. Bohn (principal investigator)
 J. J. Bisognano
 R. Li

From BNL: I. Ben-Zvi
 X. J. Wang
 X. Qiu

From LANL: B. E. Carlsten

From SLAC: T. O. Raubenheimer

Setup and execution of the experiment will largely fall to BNL with CEBAF guidance. This includes development and refinement of the beam diagnostics, analysis of the beam transport line, and operation of the facility. CEBAF has an ongoing theoretical effort which will feed into the experimental investigation. However, apart from providing travel for preparatory consultations and participation in the actual conduct of the experiment, CEBAF will likely be unable to provide any substantial resources in the form of hardware or time. Both LANL and SLAC will simulate the beam dynamics in the ATF achromat using a version of PARMELA in which the space-charge algorithm is updated to include the CSR-induced force on the particles in the bunch. LANL and SLAC will also participate in the conduct of the experiment.

This investigation is, by design, a collaborative effort. Publications ensuing from the proposed experiment will bear joint authorship between CEBAF, BNL, LANL, and SLAC, and other participants, as appropriate based on the respective contributions of the collaborators. A likely outcome is that the findings will motivate follow-on experiments for more comprehensive studies and/or experiments involving different types of bends. Should a follow-on program at ATF prove worthwhile, CEBAF and BNL will work together with other interested collaborators to structure it.

REFERENCES

- [1] See, for example, R. L. Warnock and P. Morton, Part. Accel. 25, 113 (1990) and references therein.
- [2] J. B. Murphy, S. Krinsky, and R. L. Gluckstern, "Longitudinal Wakefield for Synchrotron Radiation", Proceedings of the 1995 Particle Accelerator Conference, Dallas, Texas (in publication).
- [3] G. R. Neil, S. V. Benson, H. F. Dylla, and H. Liu, Nucl. Instr. and Meth. in Phys. Res. A358, 159 (1995).
- [4] R. L. Warnock, Proceedings of the 1991 Particle Accelerator Conference, IEEE Cat. No. 91CH3038-7, 1824 (1991).
- [5] J. J. Bisognano, private communication, March 1995.
- [6] B. E. Carlsten and T. O. Raubenheimer, Phys. Rev. E 51, 1453 (1995).

- [7] National Synchrotron Light Source Meeting Notes, "Consideration of Beam-Induced Fields in Bends -- CSCF and CSR Experiments and Theory", E. Johnson, recorder, 23-24 October 1995.
- [8] Ya. S. Derbenev, J. Rossbach, E. L. Saldin, and V. D. Shiltsev, "Microbunch Radiative Tail-Head Interaction", DESY preprint, 1995 (unpublished).
- [9] C. L. Bohn, "A Program to Research Emittance Growth in Bends", submitted for publication in Proceedings of the Microbunches Workshop, Brookhaven National Laboratory, 28-30 September 1995.
- [10] I. Ben-Zvi, private communication, 2 November 1995.