Progress Report

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UCLA Accelerator Research & Development

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This progress report covers work supported by the above DOE grant over the period November 1, 1991 to July 31, 1992. The work is a program of experimental and theoretical studies in advanced particle accelerator research and development for high energy physics applications. The program features research at particle beam facilities in the United States and includes research on novel high power sources, novel focussing systems (e.g. plasma lens), beam monitors, novel high brightness, high current gun systems, and novel flavor factories in particular the ϕ Factory. The program is carried out by members and students of the UCLA Center for Advanced Accelerators (CAA). Members and students of the CAA participating in this work are D. Cline, Director, W. Gabella, A. Garren, J. Rhoades, X. Wang, J. Kolonko, C.H. Ho, F. Keyvan, P. Kwok, C. Nantista, S. Rajapopalan, and D. Ramachandran.

Center for Advanced Accelerators (CAA)

The Center continues to be supported by UCLA. The new building on the Southwest campus which will house the CAA in 1995-1996 is still on schedule. New activities in the Center include medical imaging studies, liquid Krypton studies for the ϕ Factory detector, and studies of the ϕ storage ring as a light source. Also, studies of novel x-ray sources using RF guns and beam deflection by crystals (FNAL E853) as well as a study of particle acceleration in crystals are being carried out. The 5 million dollars which UCLA committed for ϕ Factory equipment is now endangered given the DOE position on the ϕ Factory project.

A High Current, Short Pulse Electron Source For Wakefield Accelerators at Argonne National Laboratory

UCLA graduate student, Ching-Hung Ho participated in the Phase I construction of the Argonne Wakefield Accelerator this past year. Most of the effort was devoted to the experimental investigations, with the main task to conduct high power tests of the gun cavity. Preparation and conditioning of the gun cavity was the main objective of the experiments. A series of low power level RF measurements on the gun cavity were conducted to obtain cavity characteristics and to investigate the resonant frequency tuning and RF power coupling. The cavity was optical polished and then brazed together before high power tests were performed. The result of the test showed an electric field of 80 MV/m on the center of the photocathode. This result is 87% of the design goal of 92 MV/m. Future improvements, which include a longer period (at least one week) of RF processing, a thorough chemical cleaning of inner cavity surfaces, and a better vacuum condition, should reduce the dark current and attain higher surface fields.

Other activities during the year include an analytical estimation for space charge forces and a calculation on the beam loading by dark current. Finally, C.H. Ho completed his Ph.D dissertation in June 1992 culminating several years of effort in this area.

UCLA Research Activities at BNL

In the past year, the UCLA group was involved with both the BNL ATF facility construction and the physics experiments. The major achievements are summarized below.

- Smith-Purcell Radiation Experiment

After a two week test run in early 1991, it was found that background noise was the major problem for the Smith-Purcell experiment. A major improvement of the detector was undertaken, a fiber optics system was tested and installed, and two new PMTs were purchased. A first round experiment finished in early July of 1992. Two types of grating were used for the experiment. The first one was commercial grating with a period 0.83 μm. The grating is a quartz substrate coated with allumina. The synthesized light generated, when an electron beam was intercepted by the grating dominated the signal. The second grating used is the grating designed for laser-linac acceleration experiments with period 10.6 μm. Initial data analysis showed that Smith-Purcell radiation experiment is very promising, and a report is under preparation.

We have obtained from the ATF management permission to continue the Smith-Purcell radiation experiment after some upgrades to the equipment. We proposed to purchase two copper gratings with a period 2 to 3 μm. The laser-linac grating with a large period is not suitable for visible Smith-Purcell radiation. The small angular separation between the different orders of S-P radiation and large amount orders allowed make detection very difficult and the signal very weak. The new gratings will address these problems. The new gratings will have the same period, but have a different profile. The motivation for this experiment is to study the dependence of S-P radiation on the grating profile. A new computer is needed to speed up the data aquisition process.

- Laser-Induced Explosive Electrons Emission Studies

This past year we observed laser-induced vacuum breaking in the RF cavity at the BNL ATF. We devoted a major effort to study this effect. We identified this phenomena as laser-induced explosive electron emission. Explosive electron emission is one of the major sources of the vacuum break. It can play an important role in the development of high gradient linac structures for future linear colliders. We have measured laser-induced explosive electron emission in both RF and DC fields working with Dr. T. Tsang. The experimental results were accepted for publication in the Journal of Applied Physics. The results will also be presented at the International Symposium on Discharge and Electric Insulation.

- ATF RF Gun Studies and Construction of RF Gun 1B

Working with Dr. K. Batchelor, we have developed a procedure of tuning the RF gun in the beam line. This procedure is used to study the different configurations of the RF gun pick loop in order to reduce the possibility of the pick loop and tuner as the sources of the break down.

We were also involved in the RF testing of the second BNL RF gun which is now under construction.

- Automatic Diagnostics of RF Gun

In collaboration with Dr. Ilan Ben-Zvi and Bob Molone of BNL, we are now developing on-line emittance and RF gun phase measurements. One of the crucial parameters affecting the performance of the RF gun is the RF phase. A constant amplitude phase shifter has been constructed using a two voltage controlled phase shifter. This device has been tested and calibrated. The absolute RF phase will be automatically determined by measuring the energy dependency of the RF phase.

The main feature of the on-line emittance measure is speed so we can study the relation of emittance to the laser spot size, RF phase and RF field.

The UCLA activity at BNL is largely carried out by X.J. Wang. Dr. Wang completed his Ph.D this past year and currently holds a postdoctoral associate appointment with the UCLA group.

<u>Radio Frequency Pulse Compression System Development at SLAC</u>

The next generation of linear colliders will have beam energies on the order of a TeV. They will operate at X-band frequencies with short structure fill times. The latter characteristic makes feasible new methods of compressing RF power pulses to drive them. Limitations on klystron technology, in view of the high gradients required for such linacs, make pulse compression an indispensible part of any next generation linear collider scheme. Furthermore, the need to accelerate long bunch trains makes the widely used SLED (SLAC Energy Development) technique applicable due to its decaying pulse shape.

Binary Pulse Compression is a technique by which RF power pulses are bisected in time by phase coding and 3-dB couplers, the halves then being superimposed after the leading half goes through a trombone-like delay line. The three-stage BPC we built at SLAC, in collaboration with the SLAC Accelerator Theory and Special Projects Group, has yielded up to 120 MW of output power and a power multiplication factor greater than five. It has recently been used as a driver to test new accelerator structures for the proposed Next Linear Collider Test Accelerator (NLCTA).

Another method of pulse compression, referred to as SLED-II, is similar in concept to SLED, but replaces the storage cavities with resonant delay lines, shorted at one end and coupled by irises to a 3-dB coupler at the other. Unlike SLED, it yields a flat-top output pulse. A low-power demonstration has been done, and much work has gone into planning and designing components for a high-power SLED-II system at SLAC.

Since the system will operate in over-moded circular wave-guides, Norman Kroll of UCSD and UCLA graduate student Christopher Nantista have designed and built a 3-dB coupler with circular ports. The tests show the first prototype to work about as well as the rectangular/circular General Atomics couples used in the BPC (~ 0.1 dB loss). As a necessary accessory to the coupler, C. Nantista designed a pair of offsets or s-bends to separate the output ports enough to feed into the larger diameter delay lines. The ones that were fabricated seem somewhat lossier than theory predicts, but will suffice for the initial high-power tests.

A main goal lately has been improving on a rectangular-to-circular mode converter design with the help of our collaborators in the klystron department. This is important not only for the efficiency of the final SLED-II system, but also for our ability to measure the performance of our other components with any accuracy.

In the coming weeks a test of the BPC with two klystrons (only one was previously available) is scheduled. By the end of summer, we should also have demonstrated our first high power SLED-II prototype. This will test the power-handling capacity of the 3-dB coupler. A future, second prototype will be modified for greater efficiency and will need 90° bends to transport the output to a nearby bunker for further structure tests. It is envisioned that this system will provide the blueprint for NLCTA pulse compression. C. Nantista is working on one idea with Norman Kroll for a waveguide bend that uses a modified circular cross-section to split the TE_{01}/TM_{11} degeneracy. He is also engaged in other aspects of accelerator physics and working on his Ph.D dissertation, which will emphasize high power SLED-II development.

Simulations of Plasma Focussing

Plasma focussing simulations were carried out by UCLA graduate student S. Rajagopalan in collaboration with C.K. Ng and Pisen Chen at SLAC. A new student P.

Kwok is helping with a detailed design of the plasma lens and profile monitor for the FFTB experiment.

The work of S. Rajagopalan and the SLAC collaborators involved a directed study of plasma focussing by a gas target which is ionized by the beam itself. There are two processes of ionization, impact and strong-field. The latter is very small until it reaches a critical field strength when it becomes very strong. The result is that the fractional ionization is unity. The gas target is completely ionized. The focussing of a beam by such a plasma was studied for different values of the beam density and gas density. Theoretical results from model calculations for focussing in the two extremes when the plasma forces dominate the beam forces and vice versa were compared to results of the simulation. The comparisons confirm the essential correctness of the models. Focussing of positron beams was also studied. The model calculations in this case are cruder than for the electron beam. Nevertheless, the strong focussing of positron beams was verified over a range of plasma densities. There is an ongoing effort to build a model for focussing which will eliminate the need for simulations, by providing an accurate basis for predicting the focussing strength, emittance growth and the final beam profile. The most uncertain part of the model is the calculation of emittance growth. This calculation is expected to be finished by the fall of this year.

P. Chen, C.K. Ng, and S. Rajagopalan studied the luminosity enhancement for the beams at the SLC (Stanford Linear Collider) when the beams are focused by a plasma and collide inside the same. The conclusion of a detailed study is that significant enhancement in luminosity is possible with properly tailored beams. In the case of the SLC, the presence of long tails with a large fraction of particles therein limits the overall enhancement to between 2.5 and 3 times the luminosity without the plasma. But the study overall was encouraging in providing evidence of considerable luminosity enhancement with suitable beams.

The other part of plasma focussing studied was to calculate and simulate the focussing effects with a gas target or a plasma of the Final Focus Test Beam with the goal of studying these effects in experiments at SLAC. A tracking simulation provided evidence that even with a gas target and impact ionization it is possible to see distinct focussing beyond that achieved with the FFTB, slightly relaxed. Simulations are being done currently to obtain focussing results for a plasma target and also to understand the measurement of these small sizes with currently proposed beam size monitors. There are three beam monitors under consideration. A plasma beam size monitor by an Orsay-SLAC collaboration. A laser compton scattering device from KEK. And, a bremmstrahlung device by Jim Norem at Argonne. A letter of intent to perform the experimental test is being put together for submission to SLAC under the direction of D. Cline and P. Chen.

The ϕ Factory Program

We were disappointed by the HEPAP Subpanel report but continue to work toward the construction of a ϕ Factory. Recently we have started to study an asymmetric ϕ Factory (see attached). W. Gabella and A. Garren are helping with this design. A miniworkshop on this collider will be held on October 28, 1992 at UCLA (see attached poster).

In addition to the substantial time spent preparing for the ϕ Factory reviews and talks, a fraction of time was spent last year on studying the "Phase I" ϕ Factory design. A team consisting of A. Garren and W. Gabella, with help from A. Amiry, D. Cline and D. Robin, studied the UCLA Phase I conventional (non-quasi-isochronous) ϕ Factory as originally proposed by C. Pellegrini and D. Robin. We kept the racetrack structure of the lattice; it contained 3 bend magnets in each arc. We also assumed the 4 T superconducting bend magnets as designed. With this start, we proceeded to build-up optics involving 3 cells in each arc, and 2 cells in the "far straight" (opposite the IR straight). We kept the design of the IR straight very close to the Phase I design. Our principal objectives were to shorten the ring circumference and to provide a -I transformation between identical sextupoles to increase the dynamic aperature. We found the single particle dynamic aperture to be adequate though not tremendously robust. We also found that bunch lengths in this lattice could be made about one centimeter allowing for slightly increased luminosity, or less current in the ring keeping the same luminosity.

We also took a look at a modification of this design with superconducting bends with a 5.5 T field (a maximum in one of the designs for the UCLA ϕ Factory). Our goal was the conversion of the storage ring into a synchrotron light source. The bend magnets give copious amounts of synchrotron radiation, and the short circumference gives a high repetition rate. We finally found a design with good single particle dynamic aperture. We are in the process of preparing a paper on this for publication.

Particle Acceleration in Crystals

We are contributing to the E853 effort at Fermilab. Thornton Murphy is the spokesperson and Gerry Jackson is the co-spokesperson. The experiment tests extraction of 900 GeV protons with a bent silicon crystal. It also tests the dynamics of placing and controlling small amounts of proton flux on the crystal face. W. Gabella worked with Steve Peggs (Fermilab) and James Rosenzweig on their idea to put a small number of amplitude modulations at discrete frequencies on the RF of the Tevatron to cause particle diffusion. Gabella modified a longitudinal tracking code written by Richard Kick (Fermilab summer visitor) and developed several other utility and analysis codes. Using these, we continued the investigations into the amplitude increase of the particles under varying schemes of modulation. We wrote this up as Fermilab-TM-1783 and

UCLA-CAA0092-5/92, "RF Voltage Modulation at Discrete Frequencies, with Application to Crystal Channeling Extraction." It has been submitted to the journal Particle Accelerators.

Our UCLA team at FNAL is very active. In addition to W. Gabella and J. Rosenzweig, J. Rhoades is working on the data recording systems and other aspects of the project and a new student, D. Ramachandran is working on the crystal extraction simulations, electronic components of the systems and beam monitors. In addition, D. Cline is working on the overall system for B physics using a 20 TeV extracted beam for SSC application

We also studied several other aspects of charged particle beam interactions with crystals. At the 3rd Advanced Accelerator Concepts at Port Jefferson, we presented our ideas for a "crystal accelerator" capable of very large accelerating gradients. One such concept borrowed from the work of T. Katsouleas et. al. for a side-injected (laser) plasma accelerator. It was realized in the audience that the Accelerator Test Facility at Brookhaven might be an ideal place to test such concepts.

A Possible $\mu^+\mu^-$ Collider

After the Port Jefferson meeting in June, 1992, we started to study the possibility of a $\mu^+\mu^-$ collider to discover the Higgs boson in the 100-300 GeV mass range. A recent meeting with P. Chen, A. Sessler, R. Siemann, R. Palmer and D. Cline was very encouraging. We will hold a mini-workshop in the Napa Valley area on December 10-11, 1992 (see attached poster). This workshop will be organized by the UCLA Center for Advanced Accelerators. Proceedings of the meeting will be published.

Publications and Reports

1. "A High Current, Short Pulse Electron Source for Wakefield Accelerators", Ching-Hung Ho, Ph.D, Dissertation, 1992.

2. "Comment on the CLIC Note Beam Loading of RF-Gun by Dark Current", C.H. Ho, ANL-HEP-WF-167 (March 30, 1992).

3. "High Power Tests of the Gun Cavity", C. H. Ho, E. Chojnacki, R. Konecny, and J. Power, ANL-HEP-WF-166 (Marcy 30, 1992).

4. "Measurement of Frequency Response to Temperature Change of the RF Gun Cavity", C.H. Ho and R. Konecny, ANL-HEP-AGN-14 (September 26, 1991).

5. "Modelling of the Transverse Mode Suppressor for Dielectric Wake-Field Accelerator", Wei Gai and Ching-Hung Ho, J. Appl. Phys. 70, 3955 (October, 1991).

6. "Measurement of Deflection-Mode Damping in an Accelerating Structure", E. Chojnacki, W. Gai, C. Ho, R. Konecny, S. Mtingwa, J. Norem, M. Rosing, P. Schoessow, and J. Simposn, J. Appl. Phys. 69, 6257 (May, 1991).

7. "Radio Frequency Pulse Compression Experiments at SLAC", Z. D. Farkas, T. L. Lavine, A. Menegat, R. H. Miller, C. Nantista, G. Spalek, and P. B. Wilson, (SLAC-PUB-5409), SPIE Proceedings Vol. 1407, Intense Microwave and Particle Beams II, Los Angeles, January 1991, pp. 502-511.

8. "High-Power Radio-Frequency Binary Pulse-Compression Experiment at SLAC", T. L. Lavine, Z. D. Farkas, A. Menegat, R. H. Miller, C. Nantista, G. Spalek, and P. B. Wilson, (SLAC-PUB-5451), Proceedings of 1991 IEEE Particle Accelerator Conference, San Franciso, May 1991, pp. 652-654.

9. "A High-Power SLED II Pulse Compression System", N. M. Kroll, Z. D. Farkas, T. L. Lavine, A. Menegat, C. Nantista, R. D. Ruth, (SLAC-PUB-5782), to be published in proceedings of the 3rd European Particle Accelerator Conference, Berlin, Germany, March 1992.

10. "Plasma Formation by Beam Ionization and Collisions of Beams Focussed by Such a Plasma", S. Rajagopalan, C. K. Ng, P. Chen, Proceedings of the 14th International Conference on Numerical Simulation of Plasmas, Annapolis, Maryland, September, 1991.

11. "Simulation of Luminosity Enhancement by Colliding Electron and Positron Beams in a Plasma, C. K. Ng, S. Rajagopalan, P. Chen, Proceedings of the 14th International Conference on Numerical Simulation of Plasmas, Annapolis, Maryland, September, 1991.

12. "Progress on the ϕ Factory Project", California ϕ Factory Consortuim, CAA report prepared for the HEPAP Subpanel, February, 1992.

13. "A New Concept for an Asymmetric ϕ Factory to Test CPT and Study K_L° Mesons, D. Cline, UCLA-CAA0091-5/92 report.

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