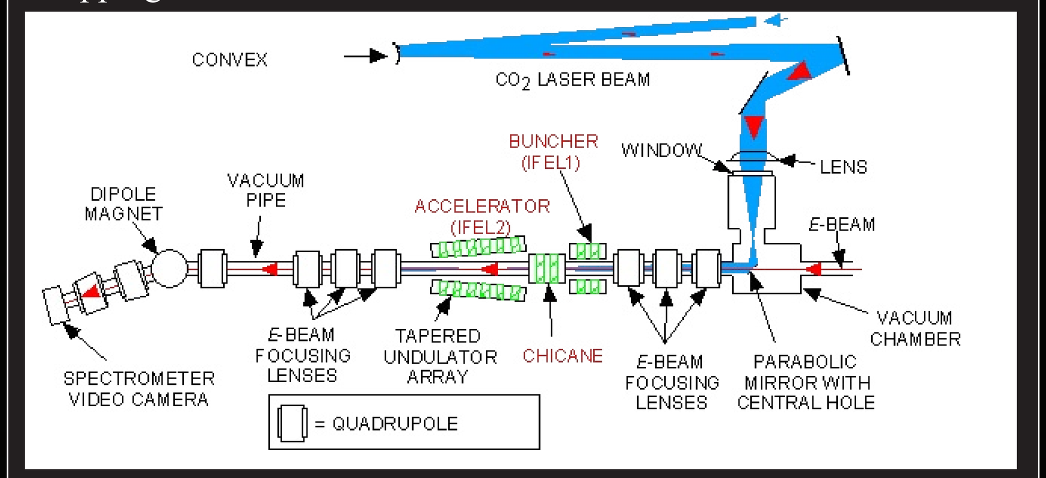
User Science at ATF

STELLA- Staged Electron Laser Acceleration

Spokespersons : W. Kimura, STI Optronics and A. van Steenbergen, BNL (UCLA, Stanford, Yale, UCSB) (1997-)

Laser-driven electron accelerators (laser linacs) offer the potential for enabling much more economical and compact devices with very high acceleration gradients. However, the development of practical laser linacs requires accelerating a large ensemble of electrons together ("trapping") while keeping their energy spread small ("monoenergetic"). This has never been realized before for any laser acceleration system until the STELLA experiment. We have demonstrated for the first time efficient, monoenergetic trapping and acceleration of electrons via laser acceleration.

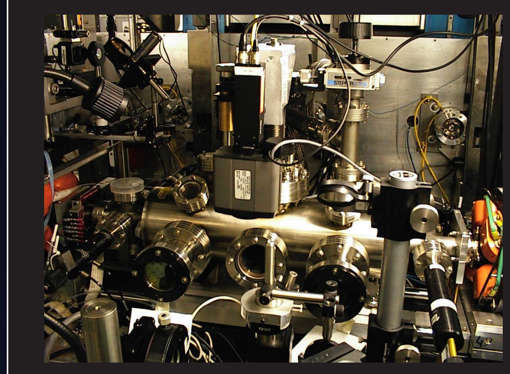


Schematic plan-view of STELLA experiment

Study of Compton Scattering of Picosecond Electron and CO2 Beams

Spokespersons: T. Kumita, Tokyo Metropolitan University, and I. Pogorelsky, BNL. (Waseda University, KEK, UCLA, Princeton U.) (1998-)

We report results of the intense x-ray generation using inverse Compton scattering of CO2 laser pulses from relativistic electron bunches. The generated number of x-ray photons was 2.5 x 10^ 7 photons/pulse and 2.5 x 10^19 photons/second. We believe that this is the strongest x-ray yield observed so far in the proof-of-principle LSS experiments. This is achieved due to the availability of a combination of the high-brightness picosecond electron beam, the high mid-IR photon flux CO2 laser at the BNL ATF and the use of a backscattering configuration. Upon completion of the ongoing ATF CO2 laser upgrade to the terawatt power and proposed electron bunch compression to femtoseconds we plan to demonstrate LSS with the x-ray yield of the order of 10^{10} photons/pulse and flux up to 10^{23} photon/sec.

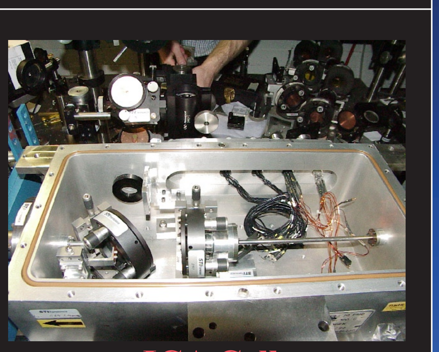


-The Compton chamber installed on the ATF Beamline 1. The electron beam enters from the left. Up front is the zinc-selenide windows for the injection and dump of the CO2 laser beam. On either end and on top one can see actuators and CCD cameras for monitoring the electron and laser beams.

Inverse Cherenkov Acceleration (ICA)

Spokesperson : W. D. Kimura, STI Optronics (BNL, UCLA) (1992-1997)

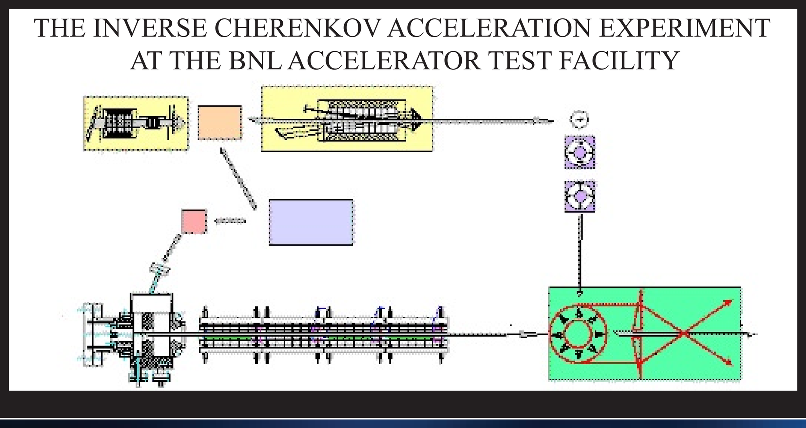
The ICA experiment at BNL demonstrated the highest energy gain for this process of nearly 4 MeV when driven by a 0.6 GW CO2 laser beam representing an acceleration gradient of 31 MeV/m. The process scales to first-order as the square-root of the laser peak power; therefore, a 100 GW laser beam would produce approximately 50 MeV acceleration.



ICA Cell

Design Parameters for ICA Experiment

Cerenkov Angle [mrad] ----------------20
Phase Matching Gas --------------------Hydrogen
Gas Pressure [atm]-----------------------2.2
Interaction Length [cm]-----------------12
Initial Electron Beam Energy [MeV]--40
Net Acceleration (@ 0.6 GW) [MeV]-----3.7



Profile of Our User's

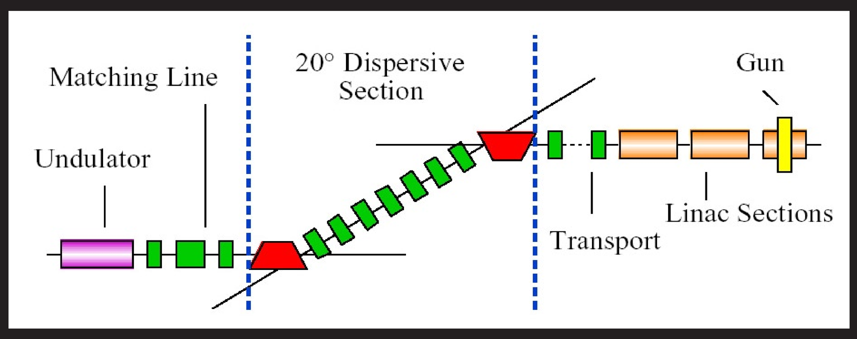
7 national laboratories
5 industries
20 universities

- **National Laboratories:** ANL, BNL, LANL, FNAL, SLAC,
- **International:** BINP, KEK, CERN, Oxford U., Tokyo Metropolitan, National Tsinghua U., Technion
- **Industries:** QEL Inc., Vista Control Systems, Omega-P Inc., STI Optronics,TR Research Inc.,
- **Universities:** Catholic U., U. of Colorado, Columbia, Darmouth, MIT, Montclare State U., U. of New Mexico, UCLA, U. of Pittsburgh, Princeton, UCSB, Stanford, U. Stony Brook, Waseda U., Yale, Northwestern
- **Graduate Students from:** UCLA (6), Stony Brook (7), Princeton (1), MIT (3), Dartmouth (1), Columbia (2), Stanford (1), Univ. New Mexico (1), Lund (1), Kent State (1), Tokyo Metropolitan Univ. (2), University of Rome (1)

A SASE-Free Electron Laser Experiment, VISA, at the ATF Linac

Spokespersons : J. Rosenzweig, C. Pellegrini, UCLA, I. Ben-Zvi, BNL (1998-)

Two types of experiments SASE FEL experiments are foreseen using the VISA system: 1) An ultra-short gain length experiment, where the bunch is compressed in the chicane and dispersive beamline transport. Saturation should be achieved well before the undulator end, allowing studies of deep saturation wavelength and angular spectra, microbunching, statistical characteristics of output, harmonic generation; and, 2) Chirped beam experiments, where one imparts a time-frequency correlation on the FEL output through a time-energy correlation in the beam. By subsequent compression of the FEL light using gratings one may shorten the FEL output pulse. Other scenarios using chirped beams to create fsec pulses at the LCLS may be partially tested in VISA II.



VISA Beamline

Inverse FEL Accelerator

Spokesperson : A. van Steenbergen, Juan Gallardo, BNL. (Yale, Columbia)

The experiments makes use of the 50 MeV linac beam and high power CO2 laser beam of the ATF in conjunction with the fast excitation (300 micro-sec pulse duration) variable period wiggler.

Worldwide IFEL Experimental Results (January 1996)

e^-		Yerevan[1]	Columbia[2]	Brookhaven/ATF[3]
Injection Energy	[MeV]	12.	0.75	40.
Energy Gain	[MeV]	0.02	0.25	0.9
Accel. Grad.	[MeV/m]	0.1	0.6	1.9
Wiggler				
Length	[cm]	20.	38.	47.
Period	[cm]	0.95	1.8-2.25	2.89-3.14
B_w	[kG]	10.	0.4	10.
CO_2 Laser,FEL*				
Power	[GW]	0.02	0.005*	1.0
Wave Length	[micron]	10.	1600*	10.6

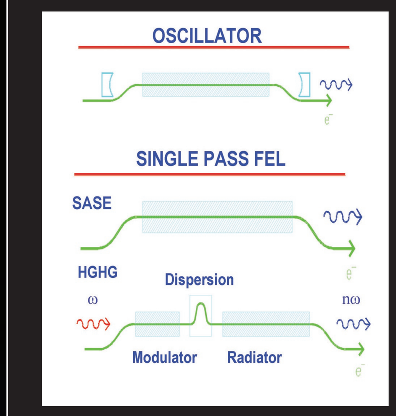
i) A. Amatuny, et. al., Proc. XIII Int. Conf. HE Accelerators, 1987.
ii) I. Wernick, T. Marshall, Phys. Rev A46, 1992.
iii)A. van Steenbergen, et. al., BNL/ATF Users Meeting, Dec. 1995.

- (top) Fast excitation wiggler for the IFEL experiment at ATF. (right) The IFEL experiment on Beam Line 2.

High-Gain Harmonic-Generation Free-Electron Laser Experiment

Spokesperson: L.H. Yu, BNL. (ANL) (1992-2001)

The FEL operates as an amplifier of a coherent signal, generated by a seed laser, thus:
- No need for resonator mirrors
- The wiggler is shorter as compared to startup from spontaneous noise (SASE)
- The bandwidth is narrower as compared to startup from spontaneous noise (SASE)
- High wavelength stability is provided by the seed laser (the wavelength does not depend on the electron beam energy)
- Adjustable pulse length through the seed. No need to change the electron pulse length
- Precise chirping is possible through the seed laser. Possibility of emptosecond pulses through optical compression
- Flexible pulse format : Single pulses, bursts, veto etc.



FEL Configurations

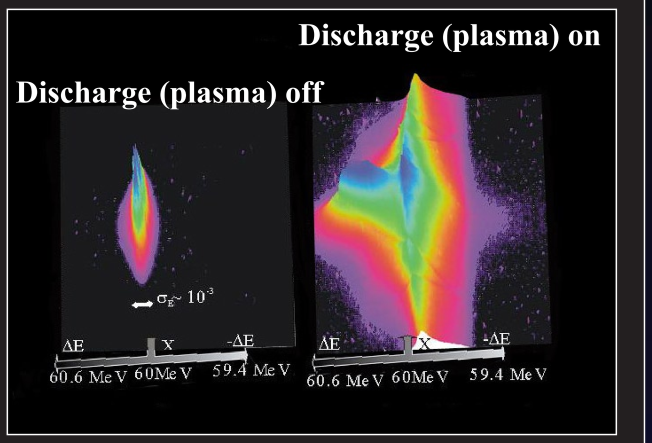
The First lasing of the HGHG Experiment
- SASE results in agreement with theory
- Seeding achieved anticipated energy modulation
- Demonstrated HGHG 10.6 um seed to 5.3 um FEL output
- HGHG output $2x10^7$ larger than spontaneous radiation
- Bandwidth and stability advantage of HGHG compared to SASE demonstrated

Plasma wake field acceleration

Spokesperson: Vitaly Yakimenko, BNL. Approved October 2002

We describe our studies on the generation of plasma wake fields by a relativistic electron bunch, and on phasing between the longitudinal- and transverse-fields in the wake. The leading edge of the electron bunch excites a high-amplitude plasma wake inside the over-dense plasma column, and the acceleration and focusing wake fields are probed by the bunch tail. By monitoring the dependence of the acceleration upon the plasma's density, we approached the beam-matching condition and achieved an energy gain of 0.6 MeV over the 17-mm plasma length, corresponding to an average acceleration gradient of 35 MeV/m. Wake-induced modulation in energy and angular divergence of the electron bunch are mapped within a wide range of plasma density. We confirm a theoretical prediction about the phase offset between the accelerating and focusing components of plasma wake.

Energy distribution and transverse beam phase space dramatically changed after a 60 MeV, 0.5nC, 3 ps (FWHM) e-beam passes through 17 mm of ~10 plasma.



MINOS Beam Monitoring Detectors.

Spokesperson: Milind Diwan, BNL. Approved: 2001. Completed 2001.

The MINOS Detector Tests At The **ATF**, (AE28), headed by Milind Diwan, completed its mission. Detectors designed to monitor beam quality via muons and tolerate the high radiation environment of the MINOS/NuMI beam line at Fermilab were tested at the **ATF** facility for linearity, stability and saturation effects. Results from the ATF measurements have demonstrated that the PIC device is suitable for operation in a high flux environment expected at the muon monitoring stations of a neutrino beam line. The 5 mm PIC operated linearly with stable response over a voltage rage 250 to 750 V with helium gas in intensities up to 10^8 particles/cm^2 for 5% saturation for short pulse beam. The results show that saturation can be modified in a controlled manner by increasing or decreasing the externally applied field. Nuclear Instruments an Methods in Physics Research, A496 (2003) 293-304.

Two schematics of the neutrino beamline showing how neutrinos are made in a long (1 km) tunnel underground. Particles called muons are also made along with neutrinos. These muons can be measured in selected locations underground, shown in the second picture.