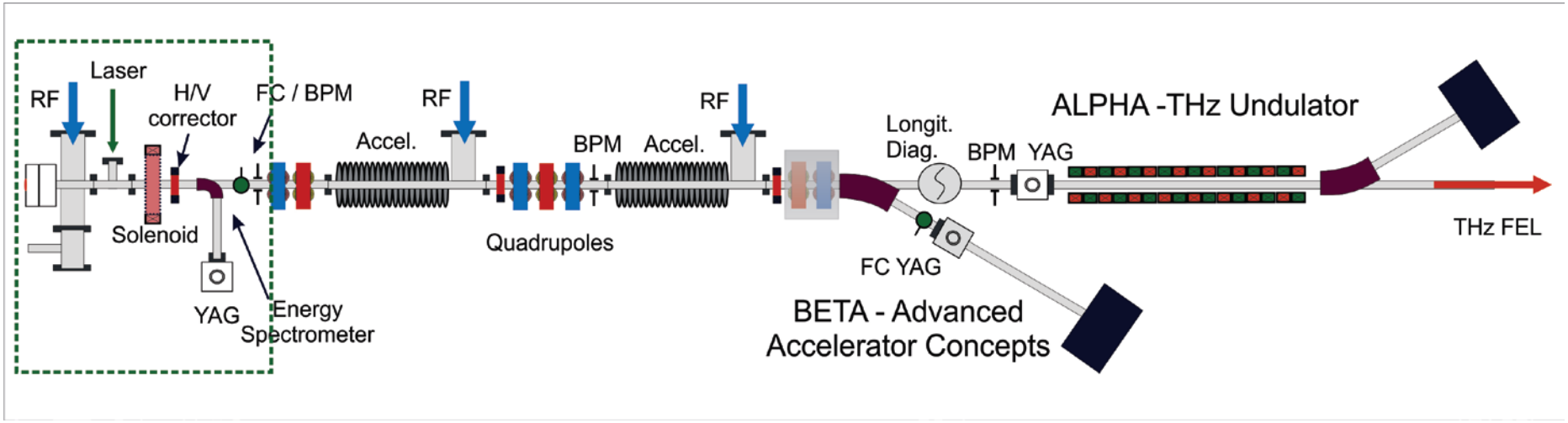
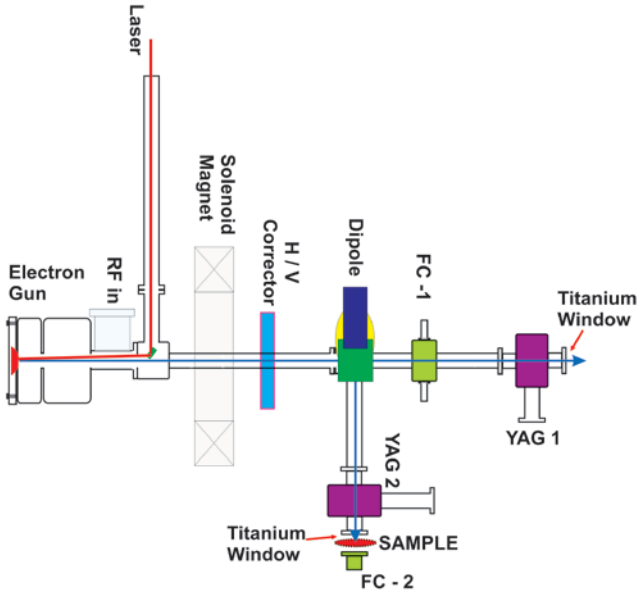
AREAL – Facility for Ultrafast Applications

B. Grigoryan

Introduction





- Laser System
- RF system
- Gun and Cathode
- Timing and Synchronization
- Diagnostics and Measurements
- Machine Upgrade
- Beam Dynamics
- Experimental Stations

Introduction

AREAL General Parameters:

Charge	10 - 850* pC
Repetition rate	1- 50 ** Hz
Transv. size (x/y)	2/3 (straight) 20 / 8 mm (dipole)
Norm. Transv. emitt. (x/y)	≤ 1*** mm-mrad
Energy	≤ 4.7 MeV
Energy spread (at dipole)	< 0.5%
Experiment duration	1 – 744**** hours

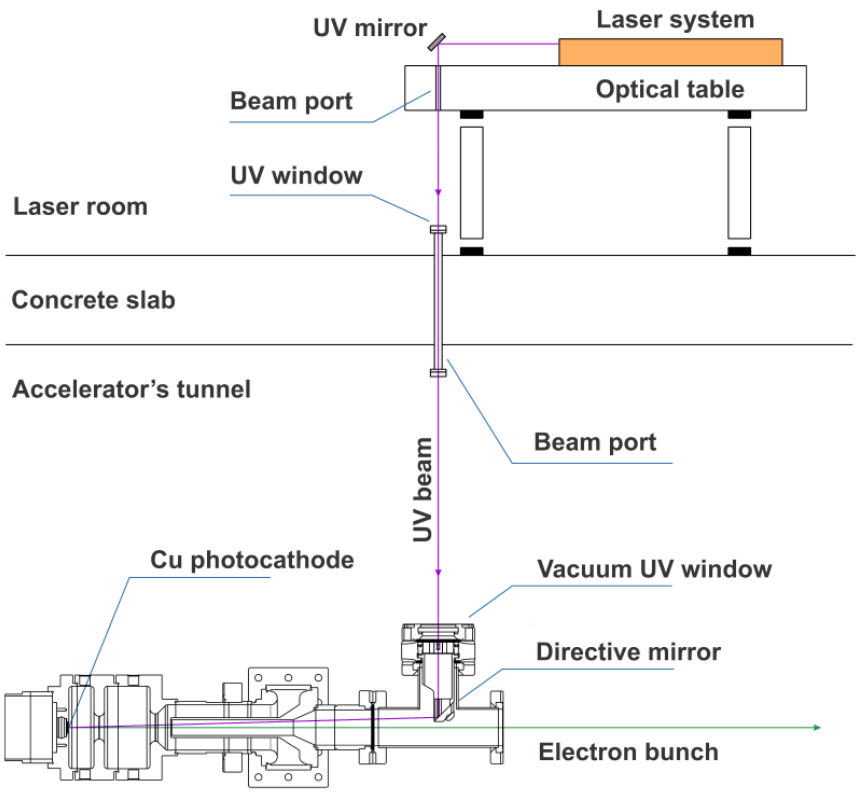
Fields of Potential Interest:

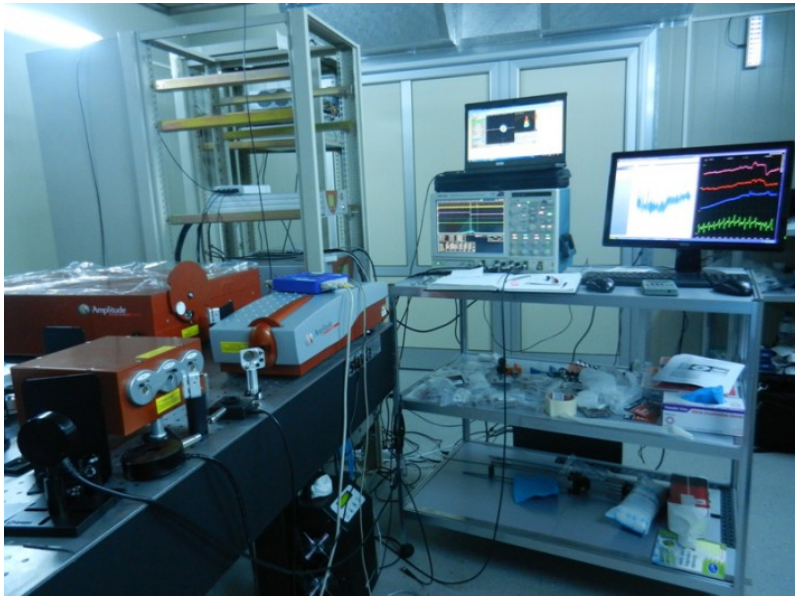
Solid State Physics
Biology
Molecular Physics
Optics
Material Science

Food Processing
Chemistry
Oncology
Medical Equipment Sterilization

* High charge regime for dedicated experiments (achieved November 2015)
** Tests were performed up to 47 Hz with nominal charge of 150 pC. (end 2015)
*** Based on ASTRA simulations. Measurements are expected at the end 2017.
**** 31 days of uninterrupted operation in May-June 2014.

Laser System

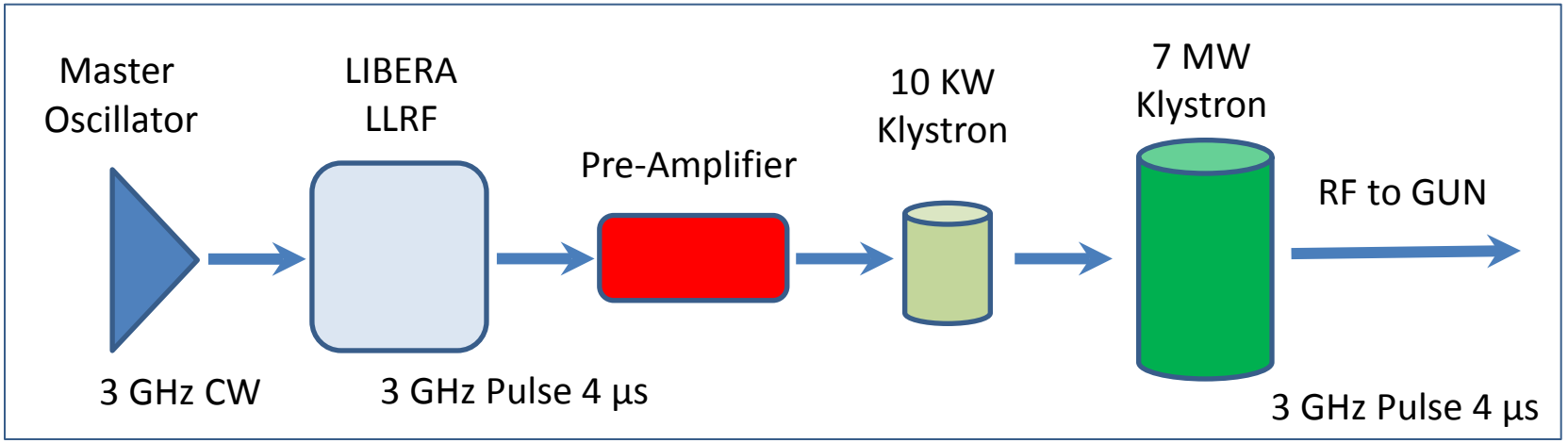




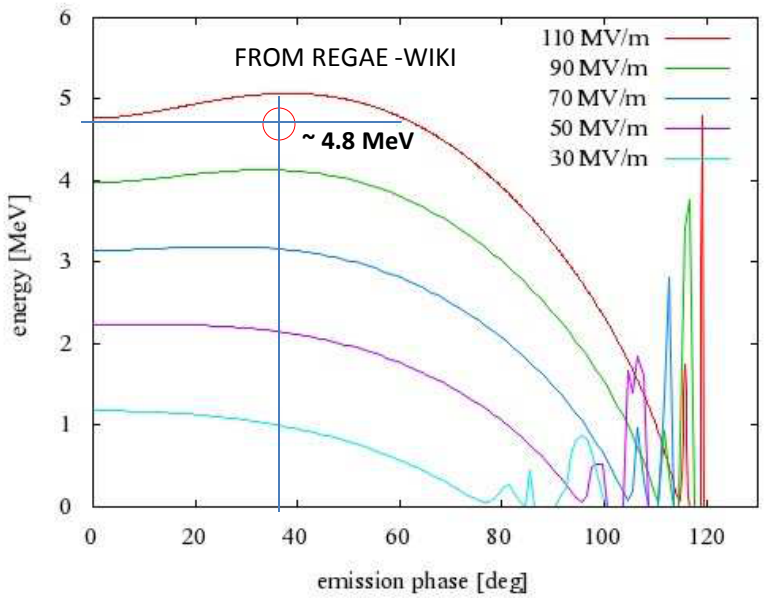
Parameters of UV laser pulse	
Central Wavelength	258 nm
Pulse energy	~400 µJ
Rep. Rate	up to 100 kHz
Pulse length FWHM	0.45-9 ps
Energy Stability 18 h	< 1.3%
Pulse-to-pulse jitter	< 0.5ps

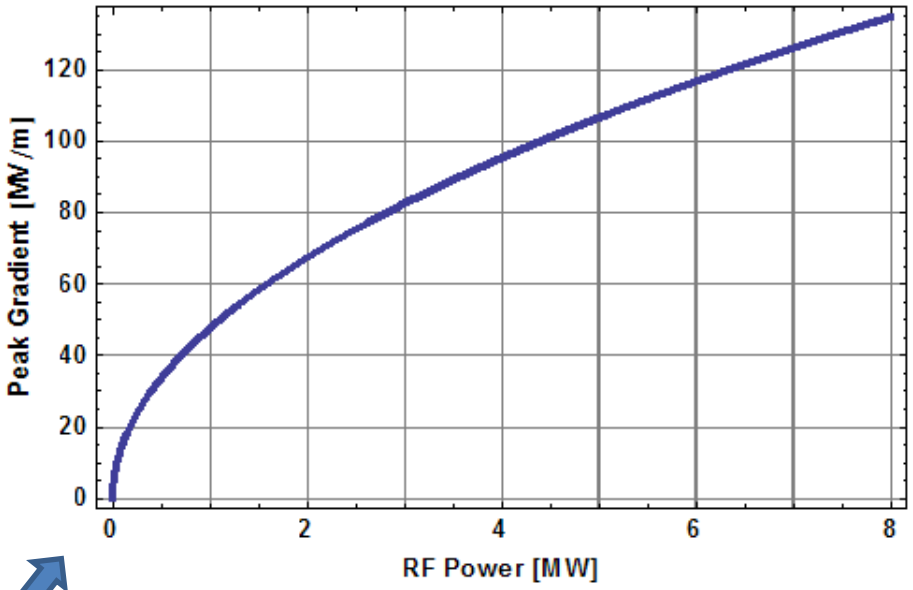
RF System

Parameters	Value
Pulse length	**4 µs**
Repetition Rate	**1- 50 Hz**
Peak Forward Power	**7 MW (Meas. 6.2 MW)**
Frequency	**2997 MHz**
HV Amplitude fluctuations	**< 1%**



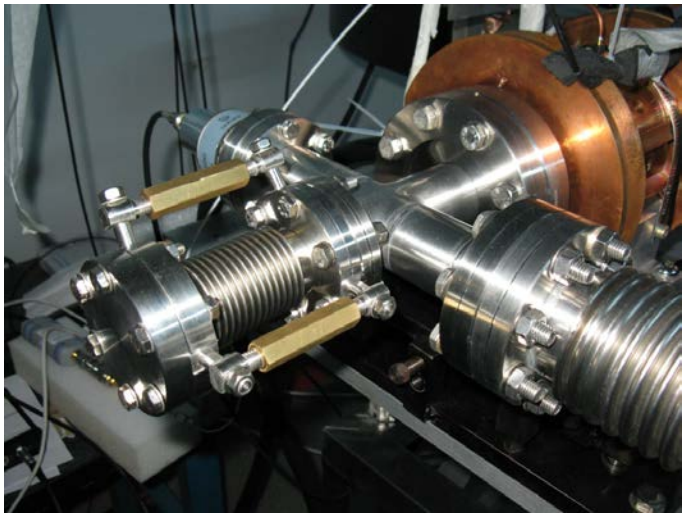
Gun and Cathode



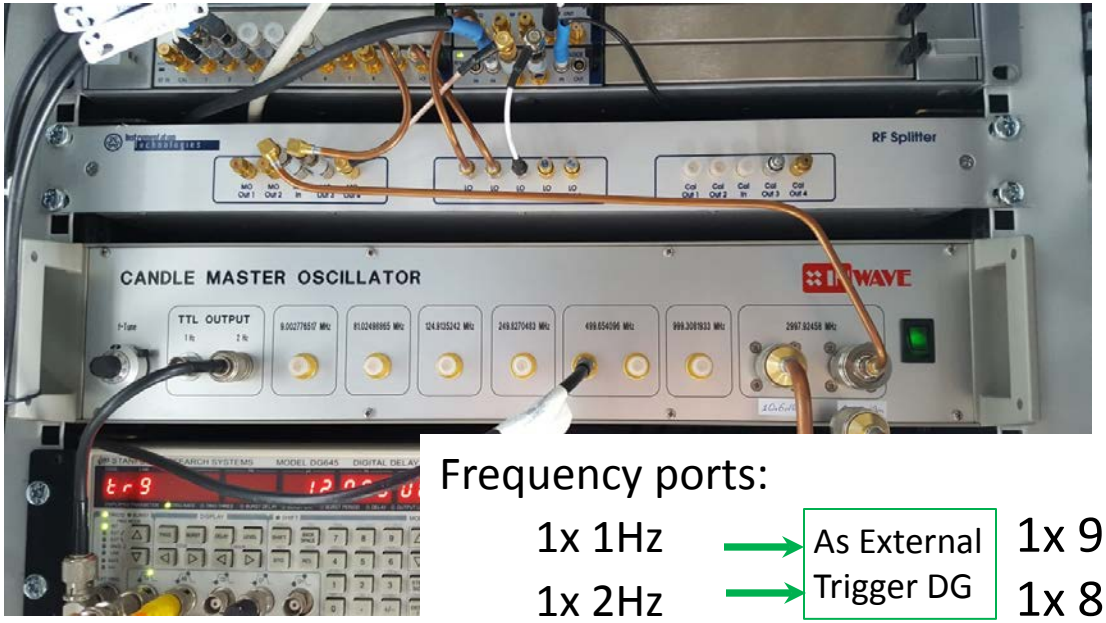


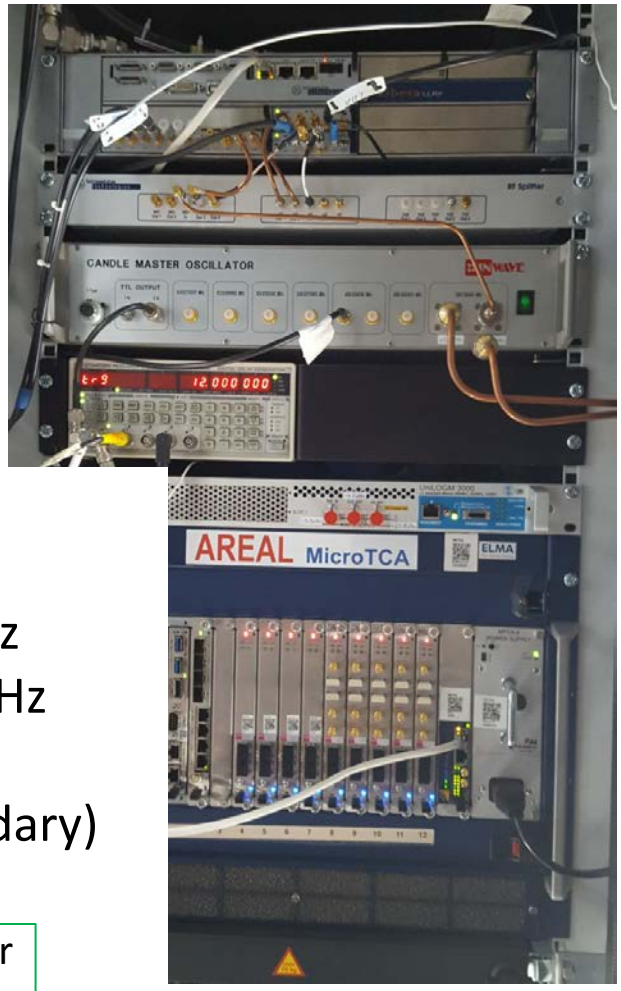
$$\hat{E}_{GUN} = 47.67\sqrt{P_{RF}}$$

FROM REGAE WIKI



Timing and Synchronization



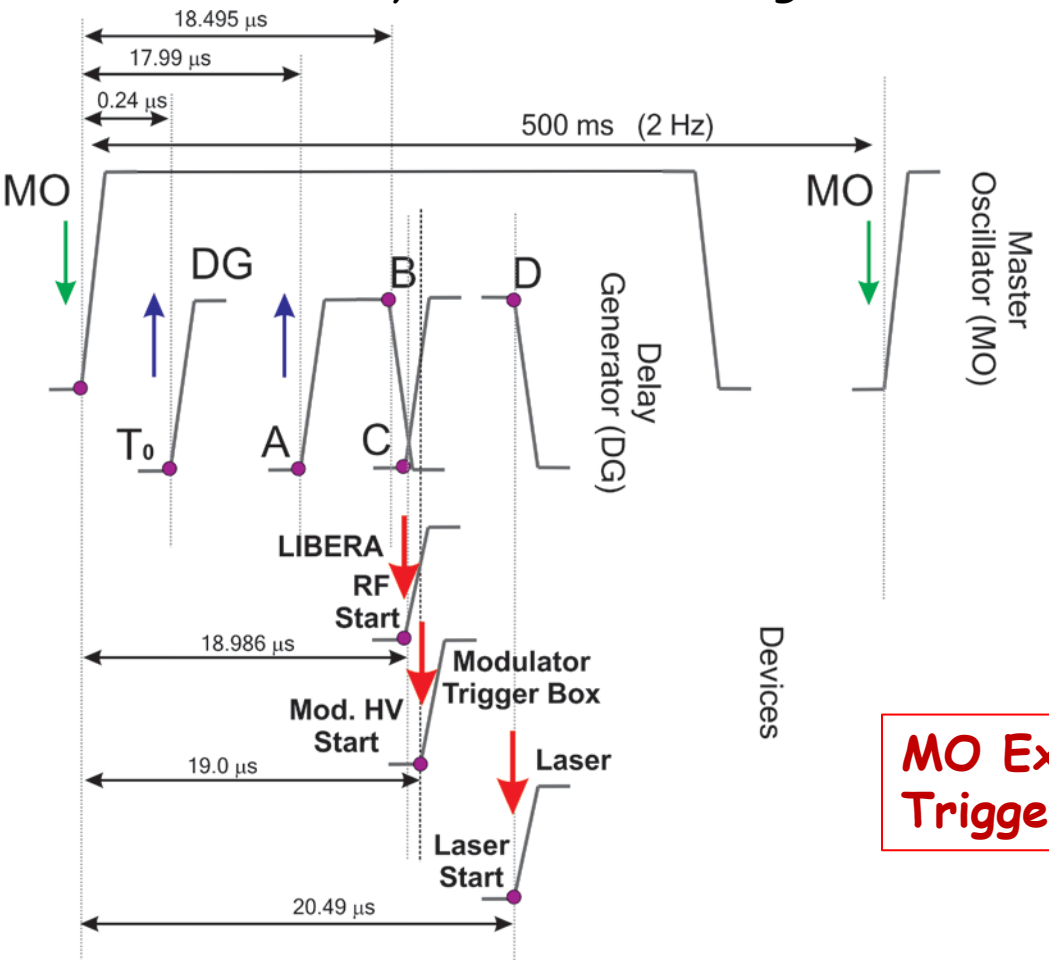


Frequency ports:

- 1x 1Hz → As External Trigger DG
- 1x 2Hz → As External Trigger DG
- 1x 9MHz
- 1x 81MHz
- 1x 125MHz
- 1x 250MHz
- 2x 500MHz → To Laser Oscillator
- 1x 1GHz → FREE
- 2x 3GHz → To LLRF
- → FREE
- 1x 9MHz
- 1x 81MHz
- 1x 250MHz
- 2x 90MHz
- 2x 10MHz (Secondary)
- 1x 10MHz (main)

Timing and Synchronization

Delay Generation using MO 2 Hz output

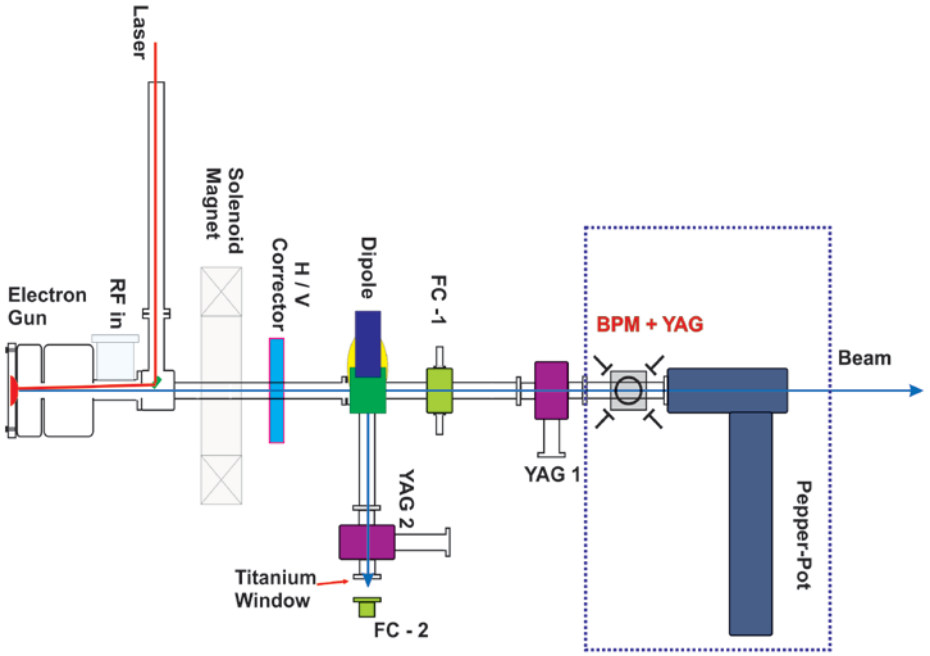


EF - MO = 690.5 ns
A - MO = 17.99 µs
B - MO = 18.495 µs
C - MO = 18.49 µs
D - MO = 20.49 µs

MO - MOD = 19.0µs

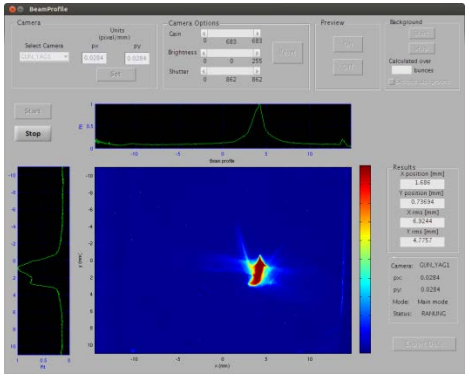
MO External Trigger 2Hz

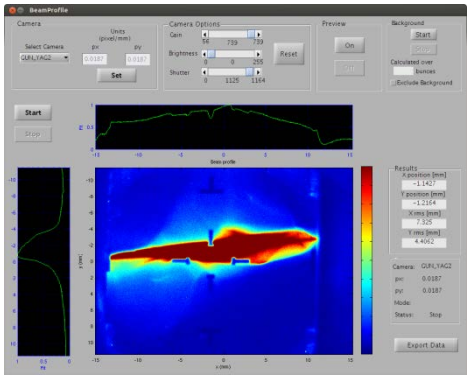
Diagnostics

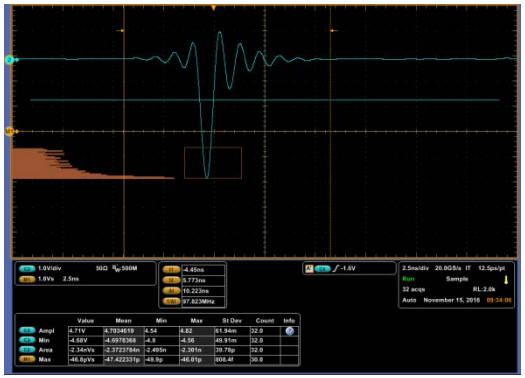


2 Quadrupoles, BPM +YAG and a Pepper-pot stations will be added to the existing layout

Transverse Profile
x / y = 4 / 6 mm





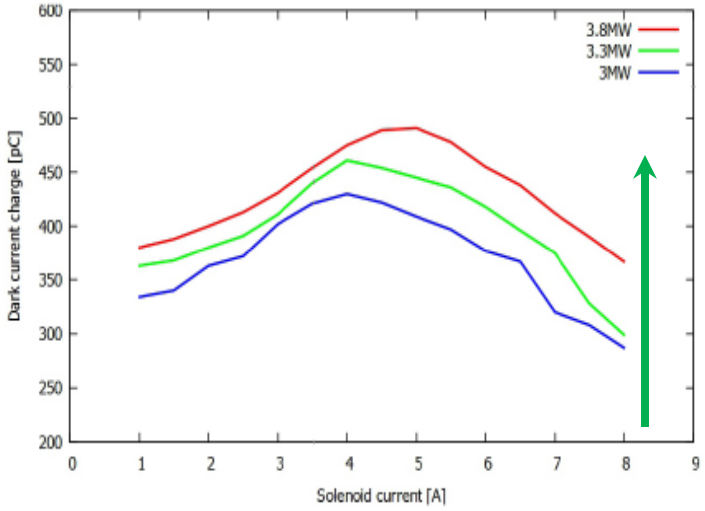


Spectrometer: profile E=4.2 MeV , Q = ~120 pC.
This set-up is not optimized for transmission and energy spread

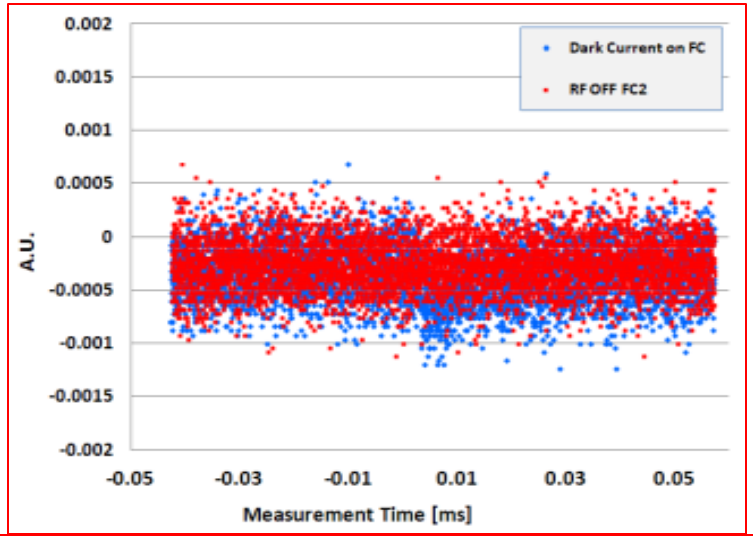
Straight FC : Charge ~200 pC

Measurements

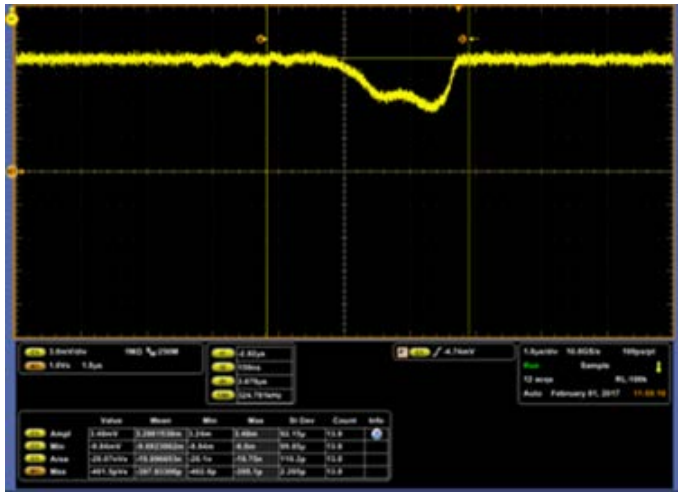
AREAL Gun Dark Current Measurements



For nominal beam operation 8.2- 8.5 A solenoid current is used



Scope Noise (Red) and Dark Current Charge (blue) measured at Spectrometer window.



Dark Current Charge vs. Solenoid Current at FC (straight) for RF power 3.8(red), 3.3(green) and 3(blue) MW

Dark current charge profile along RF pulse measured at FC (straight)

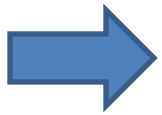
"THE STUDY OF FOCUS-DEPENDENT DARK CURRENT FOR AREAL RF PHOTOGUN"

L. HAKOBYAN, ET. AL., IPAC-17, TUPAB021.

Measurements

Instruments:
- Oscilloscope
- Autocorrelator (laser)
- Profile meter (laser)
- RF power meters
- Faraday Cup
- YAG Screens
- Dipole Magnet
- Solenoid
- Quadrupole magnets
- Pepper pot
- BPM
- YAG screens (P-p, BPM)

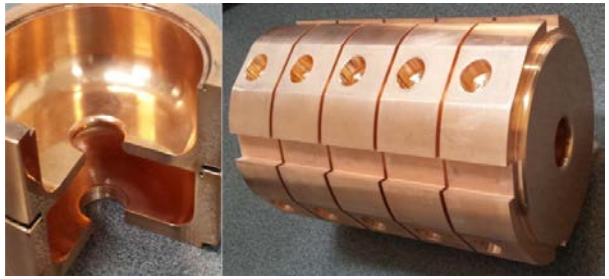
Measurements:
- Charge, Dark Current (FC)
- Energy, Energy Spread (RF and Dipole)
- Transverse Beamsize
- Laser pulse length
- Emittance (P-p, Quad, Solenoid ?)
- Charge transmission (FC and BPM)
- Beam Position
- Transverse phase space evolution ?



Optimistic Schedule: End 2017

Simulations:
A number of simulations to predict measurements and to compare expected results are planned .

Machine Upgrade. Equipment



CANDLE – DESY – PSI

Machine Upgrade. Equipment

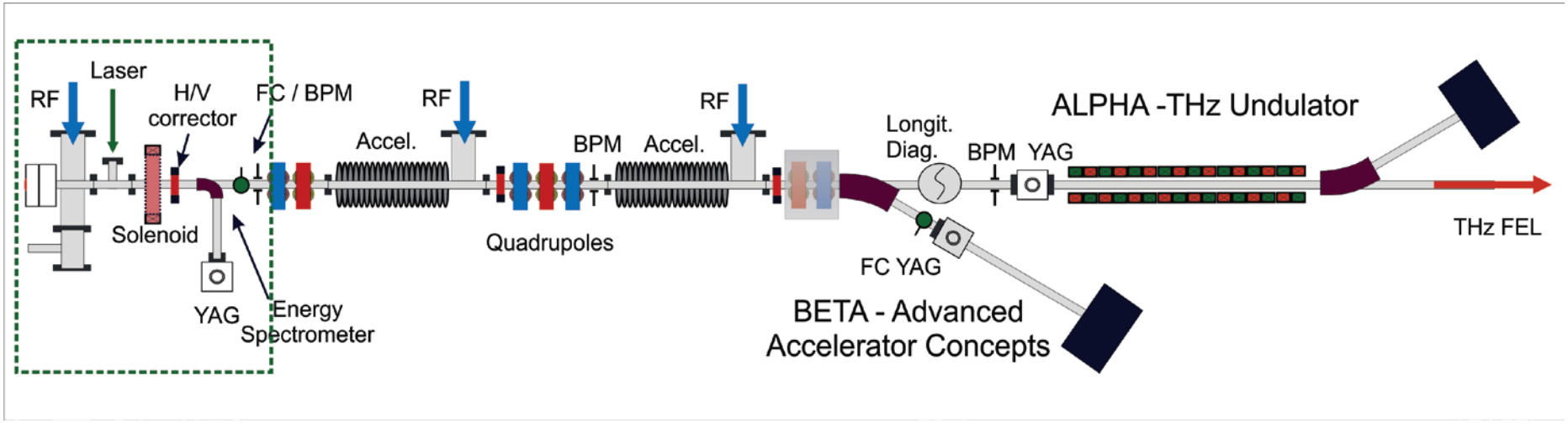
Main components expected for installation:

- ✓ RF Stations and Accelerating Sections
- ✓ Quadrupoles
- ✓ Dipole (High Energy)
- ✓ Longitudinal Beam Diagnostics
- ✓ YAG stations, Charge Meas., Transv. Diagn.
- ✓ Beamline Equipment:

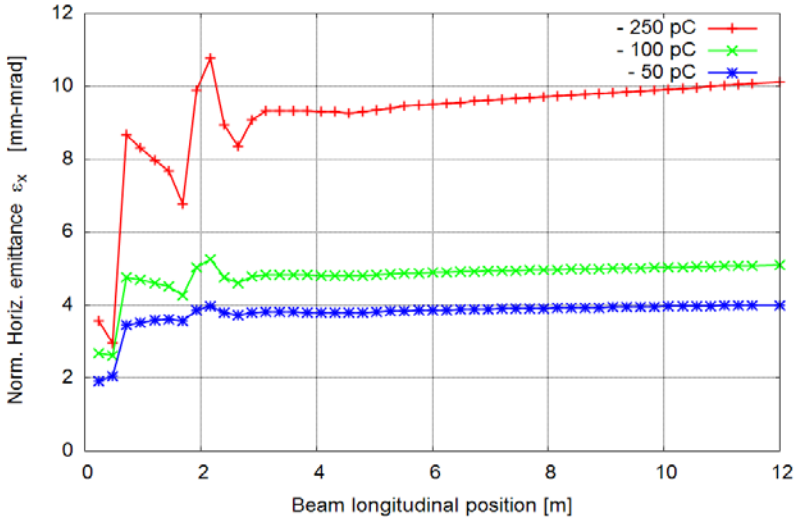
  (electron – BETA, photon – ALPHA)
- ✓ 2 Electron Beam Dumps

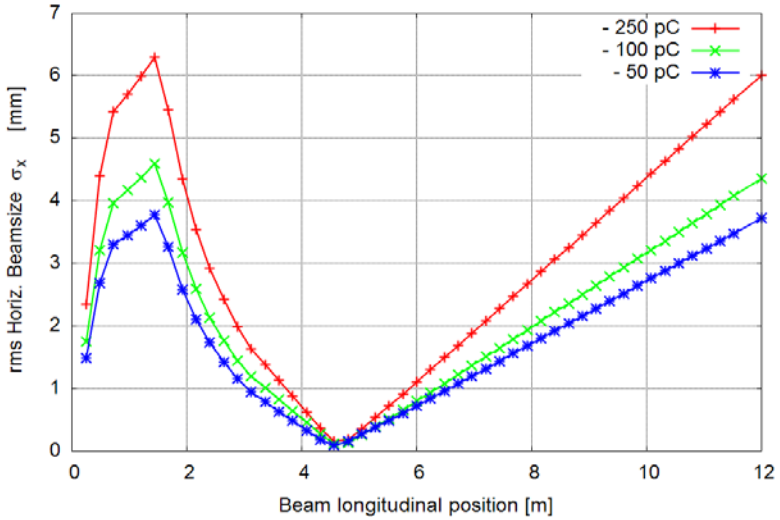
To modify:

- Tunnel (prepare for 50 MeV)
- Timing blocks & Synchronization
- Electronics and Power Supplies
- Control System
- Diagnostic System



Beam Dynamics for 50 MeV





Electron Beam at cathode	
Charge	250pC
Longitudinal distrib. / FWHM length	Gaussian / 450 fs
Transverse distrib. / size (x, y)	Gaussian / (2mm, 2mm)
Machine elements	
Gun peak gradient	115 MV/m
Solenoid -field center from cathode	0.58 m
Solenoid –field strength maximum	0.225 T
Acc. section 1 – gradient	22 MV/m
Acc. section 1 – position from cathode (minimum)	1.5 m
Acc. section 2 – gradient	18 MV/m
Acc. section 2 – position from cathode	4.0 m

Simulation has been done for the existing machine set-up, two S-band accelerating sections were added.

No other elements, tracking beam up to undulator entrance.

A lot of optimizations must be done to reach the target (design) values of main parameters at undulator entrance.

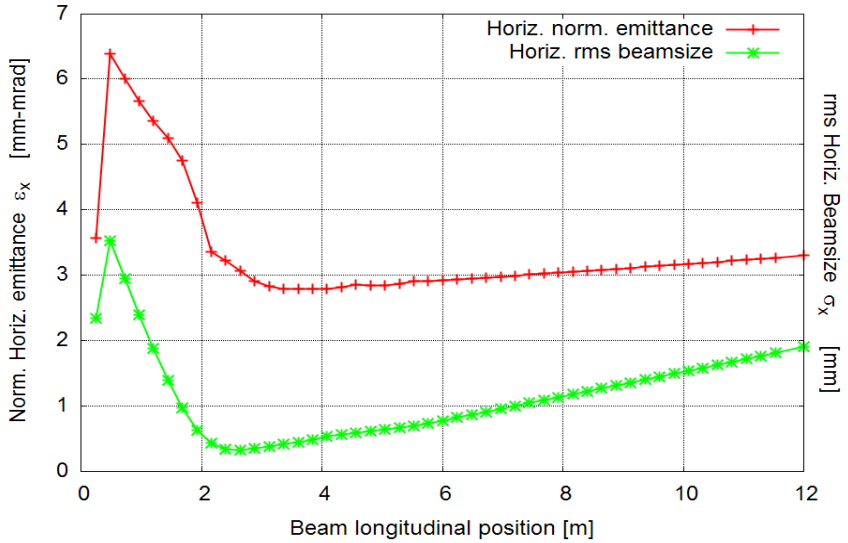
Beam Dynamics for 50 MeV

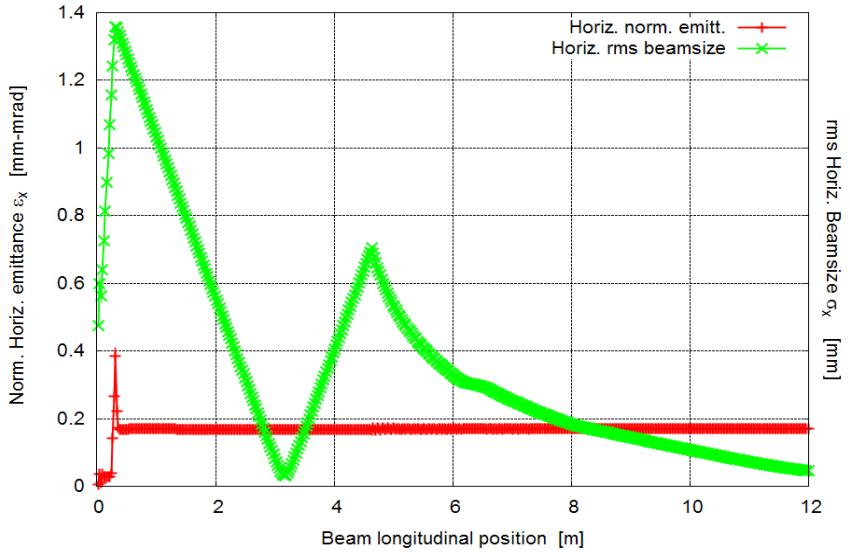
Parameters @ undulator entrance	Value
Transv. normalized emittance	10.09 mm – mrad
rms transverse beamsize	6.0 mm
Beam energy	51.2 MeV
rms energy spread	93.2 keV (0.18%)
Correlated rms energy spread *	91.3 keV (0.17%)
Beam charge	250 pC
rms bunch length	0.29 mm (0.89 ps)

* RF phase is adjusted for maximum energy gain.

→ < 1.5 mm – mrad
→ < 4 mm
→ ~ 50 MeV
→ < 0. 15 %
→ < 0.1 %
→ 250 pC
→ ~ 0.6 ps

- The optimization of machine existing elements is currently in progress.
- The addition of new elements is under discussion





Solenoid -field center from cathode	0.4 m	(was 0.58)
Solenoid –field strength maximum	0.330529 T	(was 0.225)
Acc. section 1 – gradient	24 MV/m	(was 22)
Acc. section 1 – position from cathode (minimum)	2.2 m	(was 1.5)

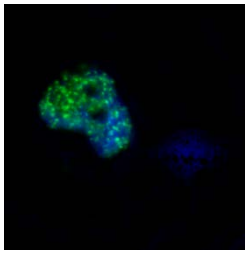
Experimental Stations

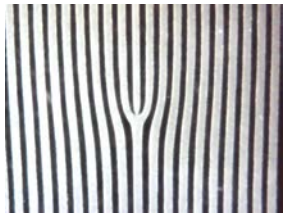
Ongoing Experiments 2015-2017:

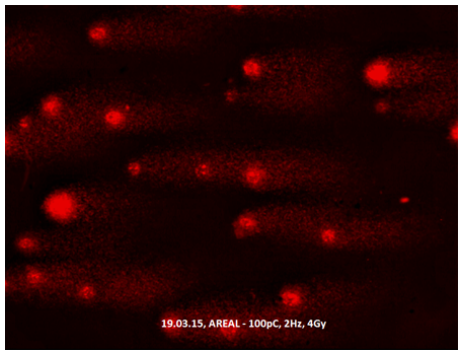
1. YerPhI (Semiconductors)
2. YSU (Genetics)
3. NAS RA (Molecular physics)
4. NPUA (Microelectronics)
5. CANDLE (EM fields)

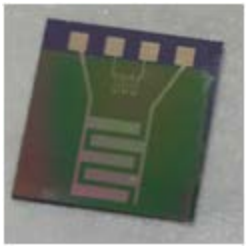
Upcoming Experiments. Starting 2017:

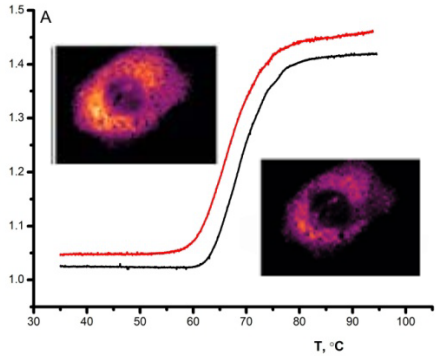
1. YerPhI (Semiconductors)
2. YSU (Genetics)
3. NAS RA (Molecular physics)
4. State Agrarian Univ. (Food Processing)
5. CANDLE (EM fields)

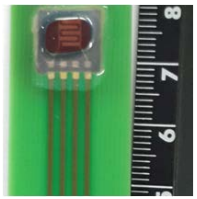












Operating Parameters:

Charge	30 - 50 pC
Repetition rate	2- 15 Hz
Transv. size (x/y)	20 / 8 mm
Energy	2.8 – 4.7 MeV
Av. exper. duration	1 – 8 hours

Experimental Stations

AREAL laser beam splitting

AVESTA laser – New possibilities

Two photon microscopy + Laboratory of Biology

ALPHA – THz FEL

Photons

5, 20, 50 MeV electrons (in vacuum + in-air)

RF Laboratory Development + BETA Station

Laser pulse compression for
tenth of femtosecond long pulse generation

Electrons

Other possibilities: Material Science Laboratory, Workshop, Vacuum Ovens, etc.

Thank you for attention !