ESLS2020

CANDLE Project Status

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ESRF, 16-17 Dec 2020

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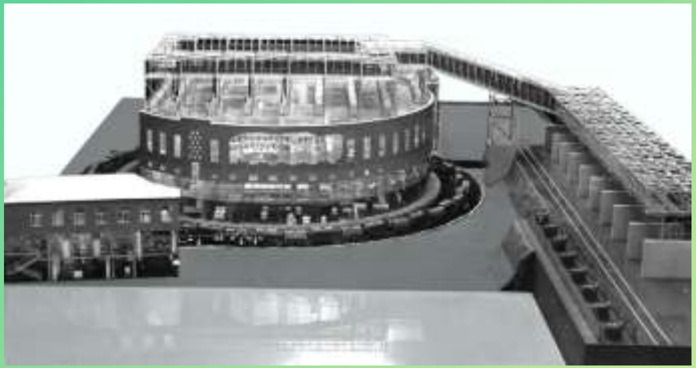
Introduction

A.I. Alikhanian



Construction of 6 GeV synchrotron (1967)

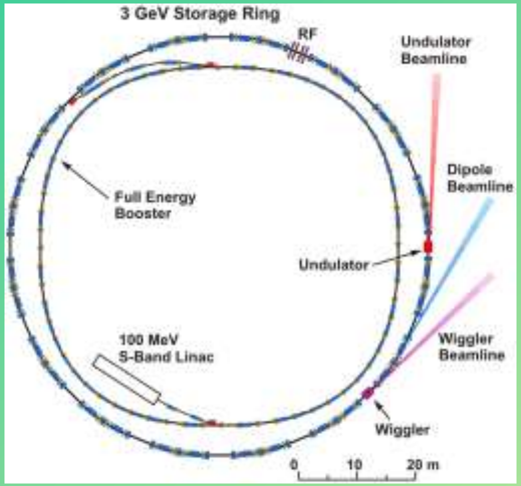
1971-1975 – Three Synchrotron Radiation Beamlines

Lab. of Radiation Solid State Physics

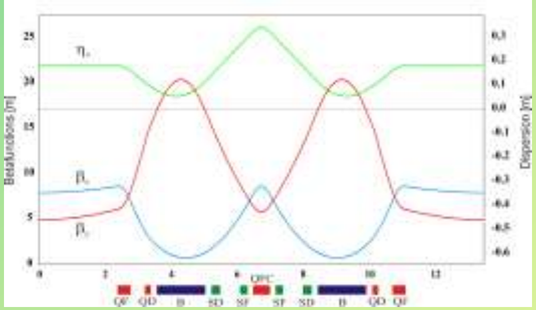
Lab. of Radiation Biophysics

Solid State Dept of Yerevan State Univ.

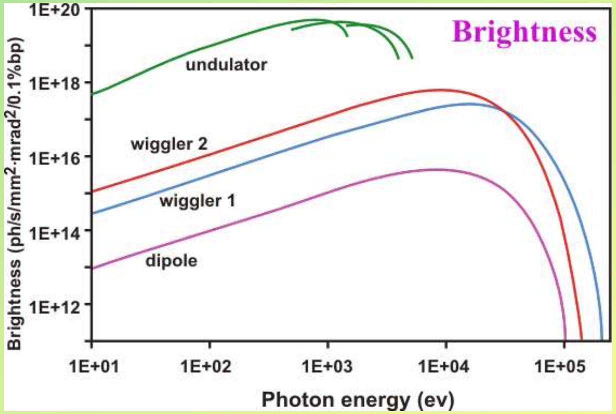
2002 – CANDLE Synchrotron Light Source Project



Energy	3 GeV
Current	350 mA
Circumference	216 m
Emittance	*8.4 nm*



DBA lattice



- "CANDLE is a world-class project enabling frontier research in a whole spectrum of basic and applied sciences.

- Excellent investment from scientific-technical point of view.

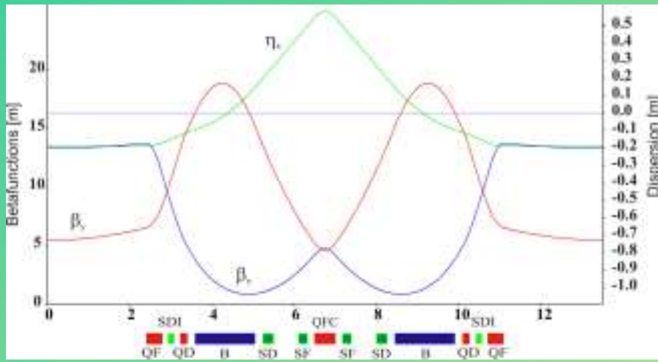
- Strong user community will emerge as the facility is readied.

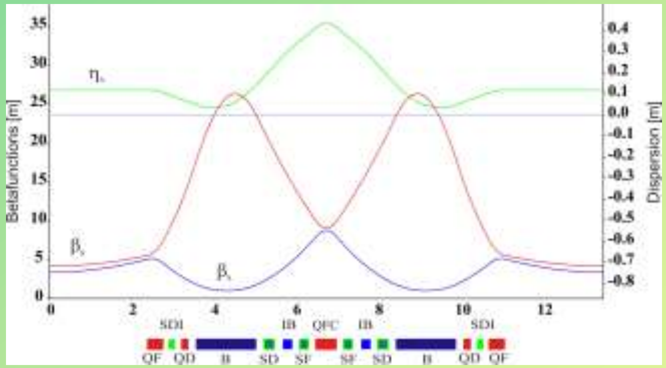
From Panel Report

2015

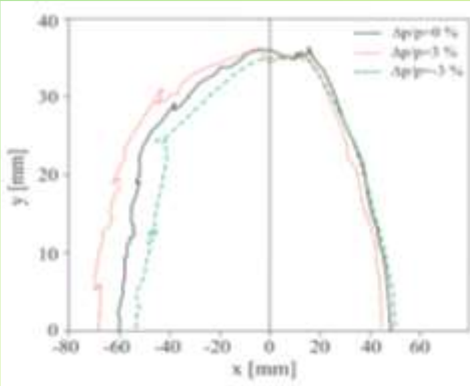
Low ALPHA Mode

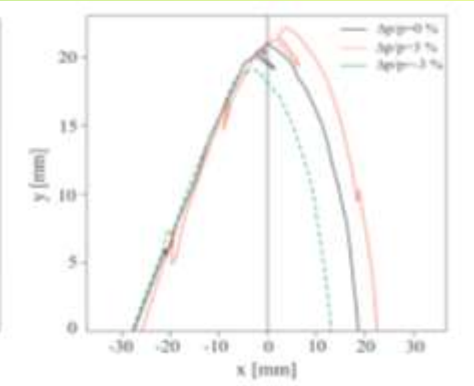
- Short pulse SR
- Coherent THz Rad





Parameter	Original lattice	High emittance lattice	Low emittance lattice
α_0	$2*10^{-3}$	$2*10^{-5}$	10^{-4} ($2*10^{-5}$ is infeasible)
α_1 (with/without sext. opt)	$3*10^{-3}$	10^{-4}/$-7.3*10^{-3}$	$4*10^{-3}$/$6.3*10^{-3}$
Emittance (nm rad)	8.4	59	27
rms energy spread (%)	0.104	0.095	0.116
Momentum acceptance (%)	2.4	10	1.25



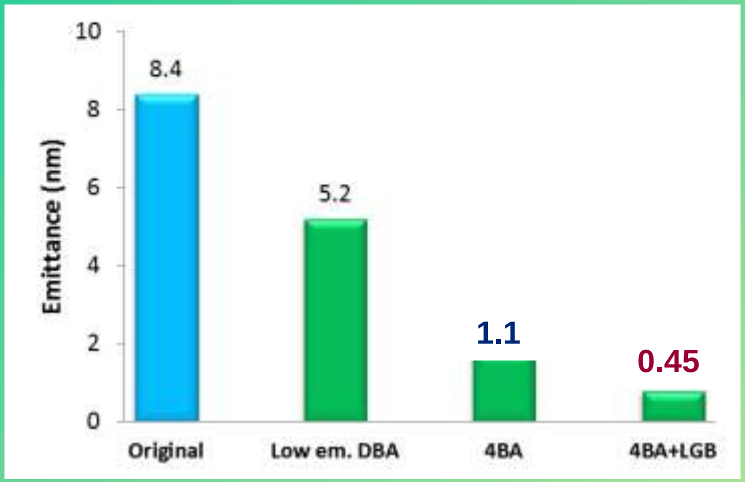


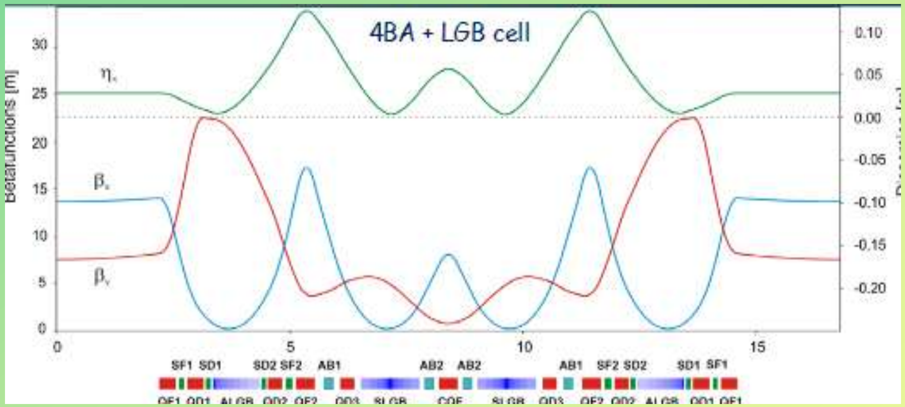
A.Sargsyan et al, JINST, 2015

2017

Low Emittance Ring

A.Sargsyan et al, NIM-A, 2017

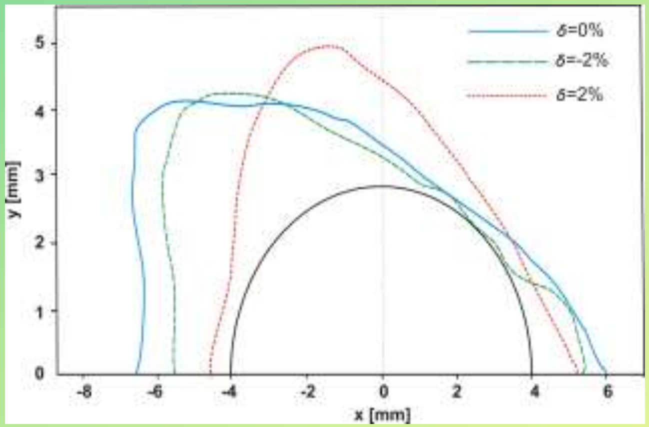




Parameter	Original	Low emit. DBA	4BA	4BA+LGB
Circumference (m)	216	216	258	268.8
Number of periods	16	24	16	16
Straight section length (m)	4.8	4.4	4.2	4.4
Energy (GeV)	3	3	3	3
Emittance (nm rad)	**8.4**	**5.2**	**1.1**	**0.435**
Energy spread (%)	0.1	0.15	0.1	0.11
Overall mom. acc. (%)	2.4	2.1	3.9	2.6
Natural chrom. (hor./ vert.)	−18.91/ −14.86	−13.64/ −24.27	−38.27/ −26.04	−95.16/ −33.92
Betatron tunes (hor./	13.2/4.26	14.17/3.19	24.61/14.37	29.2/8.36

Low Emittance Ring – 0.45 nm

- Multi-Bend Achromat
- Combined function magnets
- Longitudinal Gradient Bends
- Anti-Bend magnets

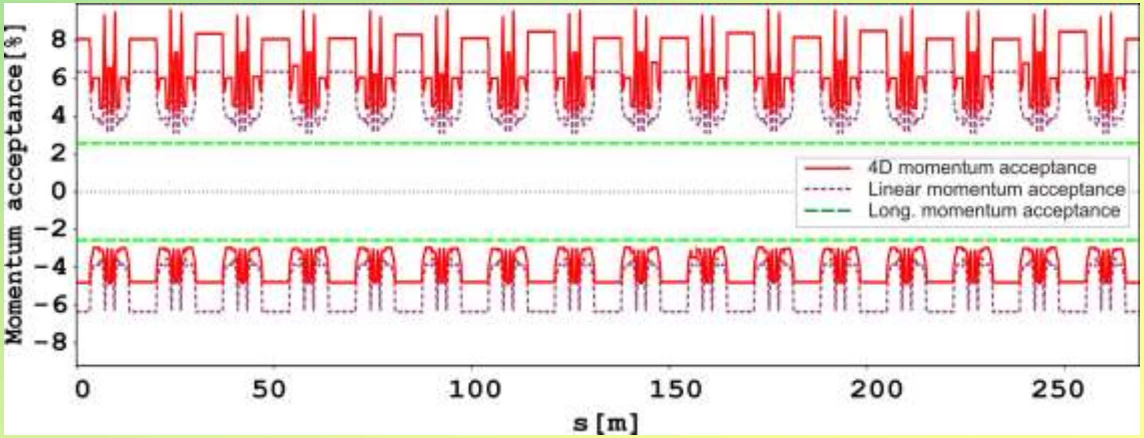


Dynamic Aperture

$$\alpha(\delta) = \alpha_0 + \alpha_1\delta + O(\delta^2)$$

$$\alpha_0 = 1.13 \cdot 10^{-4}$$

$$\alpha_1 = 2.15 \cdot 10^{-3}$$



Momentum acceptance of the new lattice 2.6%.

A.Sargsyan et al, NIM-A, 2017

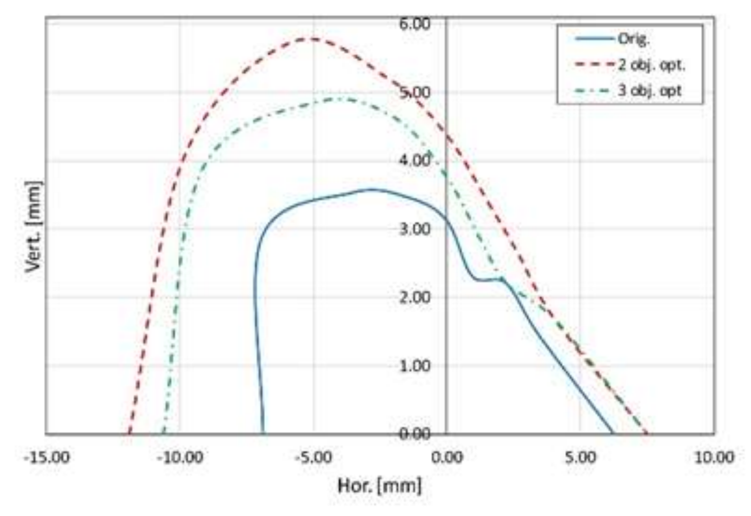
2019

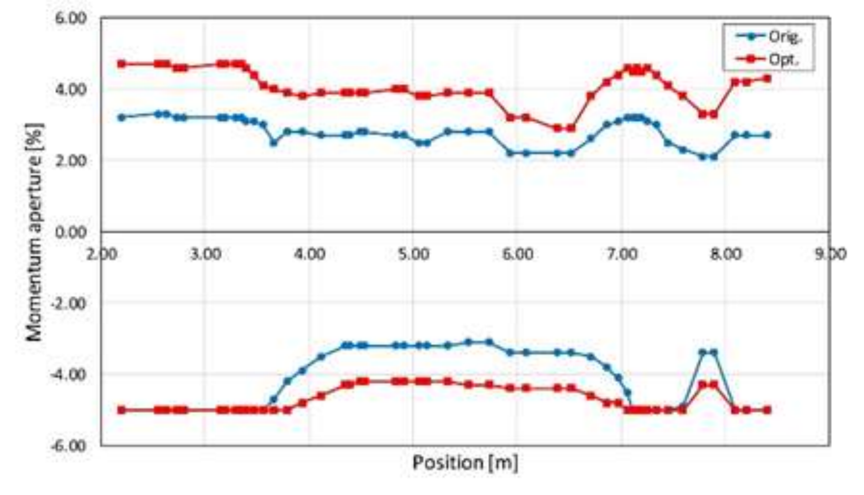
Nonlinear Dynamics Optimization with multi-objective particle swarm optimization algorithm

Parameter	Value
Circumference (m)	268.8
Lattice type	4BA
Number of periods	16
Straight section length (m)	4.4
Beam Energy (GeV)	3
Hor. emittance (nm rad)	0.435

Table 1. Sextupole strengths

Sext	Original [m^{-3}]	Optimized [m^{-3}]
SF1	110.1	113.7
SD1	-425.4	-406.3
SD2	-516.4	-544.4
SF2	313.2	347.8
AB1	-59.9	-75.5
AB2	211.6	166.9



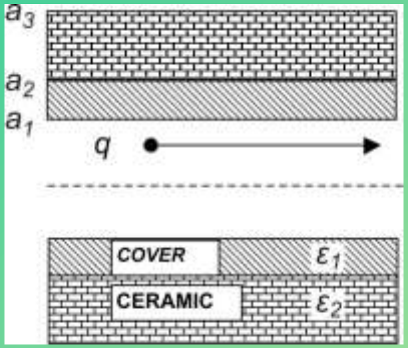


X: (- 12 ; 7) mm
Y: 5.7 mm

A. Sargsyan et al, JINST, 2019

Wakes and Impedances

Laminated structures



Field Matching

M. Ivanyan et al, PRSTAB,17 2008

Q_n– Field Transformation Matrix of 1 layer

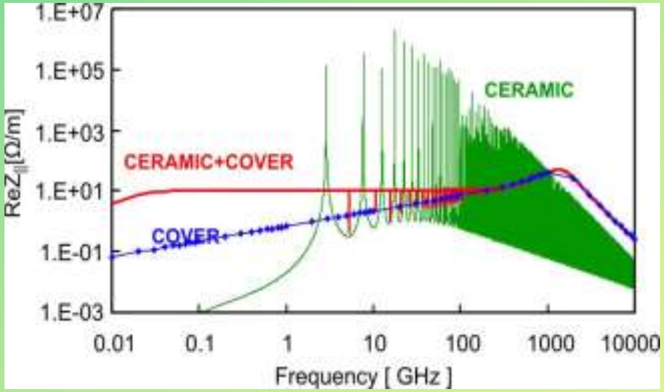
$T=(E_z,E_\theta, B_z,B_\theta)$ - vector of tang. Comp.

$$T_{in}=Q_1\cdot T_2=Q_1\cdot Q_2\cdots Q_N\cdot T_{out}$$

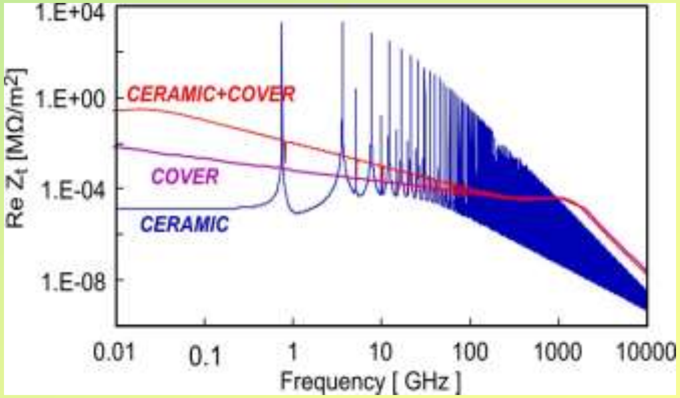
$$Q=Q_1\cdot Q_2\cdots Q_N$$

European XFEL kicker

Ceramic pipe coated with thin metallic film of Titanium-Stabilized High Gradient Steel .



Longit impedance



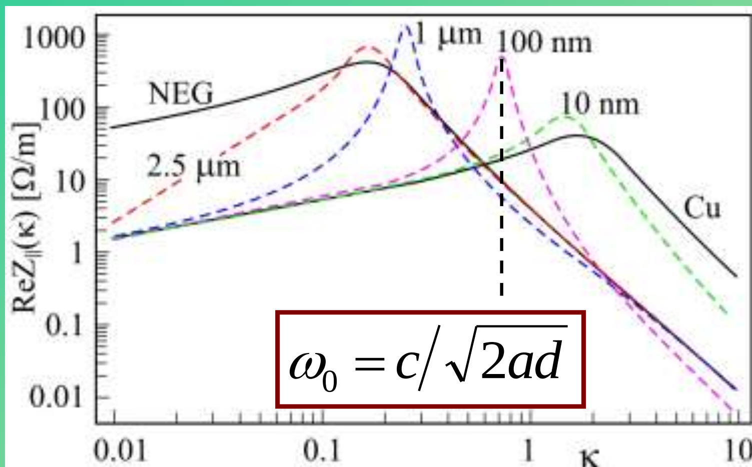
Trans. dipole impedance

A. Tsakanian et al, EPAC 2008,

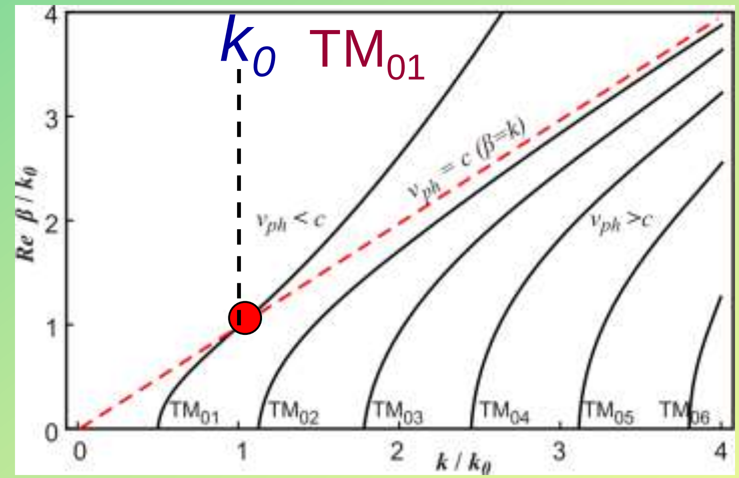
Wakes and Impedances

Cu-NEG

$$k_0 = 1/\sqrt{2ad}$$



Longitudinal Impedance

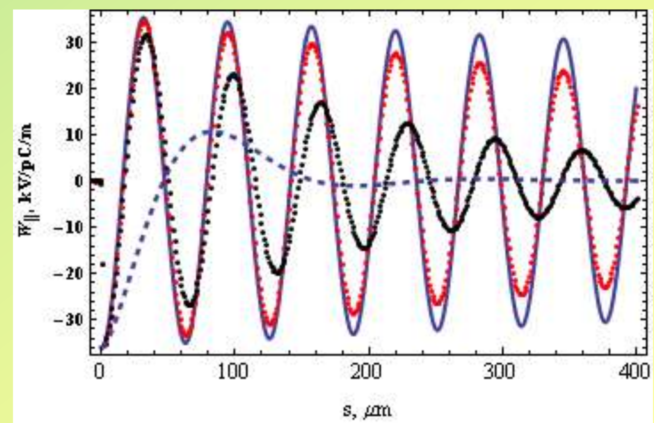


Dispersion curves

$$W_{\parallel}^{0}(s) = -\frac{Z_0 c}{\pi a^2} e^{-\alpha s}\left[\cos(ks) - \frac{\alpha}{k}\sin(ks)\right]$$

$$\sigma_1 = 3\cdot 10^4 \Omega^{-1} m^{-1}$$

$$\sigma_1 = 3\cdot 10^5 \Omega^{-1} m^{-1}$$



Longitudinal Wake functions

M. Ivanyan, et al, PRSTAB, 2014
M. Ivanyan, et al, NIM (A), 2016

2010 DESY-PSI- CANDLE collaboration Workshop

Experts meeting with RA Prime –Minister

Exit Scenario

- State-of-the-art facility
- Multiple applications
- Small facility + Lim invest.
- Scientific & Techn asset
- Training and Educ. Center
- International cooperation
- Strategic Highlightts

Ultrafast Science and Technology

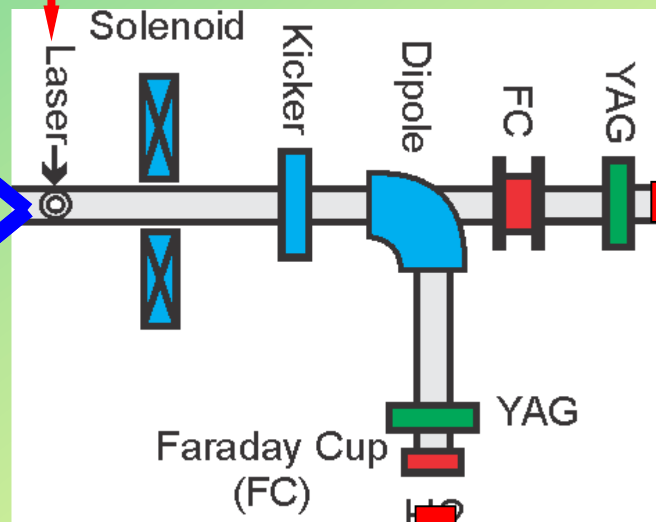
AREAL facility

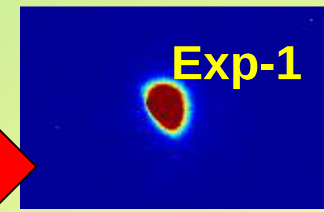
AREAL-5 MeV

Energy	2.5- 5 MeV
Time structure	0.4 – 8 ps
Emittance	~ 1.2um
Charge	300 pC
Repetition rate	1-50 Hz

UV–258 nm

MicroFab





Biomedicine

V.Tsakanov et al, NIM (A), 2016

Advanced Technologies


Laser System


Ultrafast electronics


Civil engineering


Ultrahigh vacuum


Precise machining


Radiophysics System


Diagnostics & Control


Magnet system

2015-2020 – Experimental program

Proposals -28
Institutions –12
Scientists – 96

Genetics

Molecular Physics

Biology

Yerevan State Univ
Engineering Univ.
Agrarian Univ.
Yerevan Phys. Inst
Inst. Mol. Biology
Inst. Phys. Research
Inst of Biotechnology
CANDLE Institute
Inst of Med Biophysics (Russia)

Microelectronics

New materials

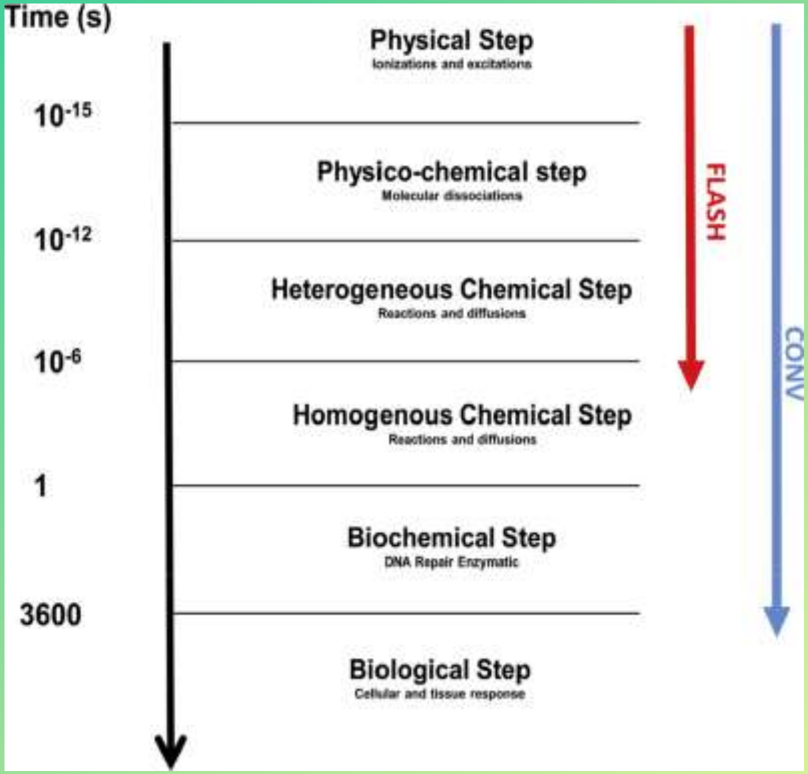
Solid State Physics

Oncology

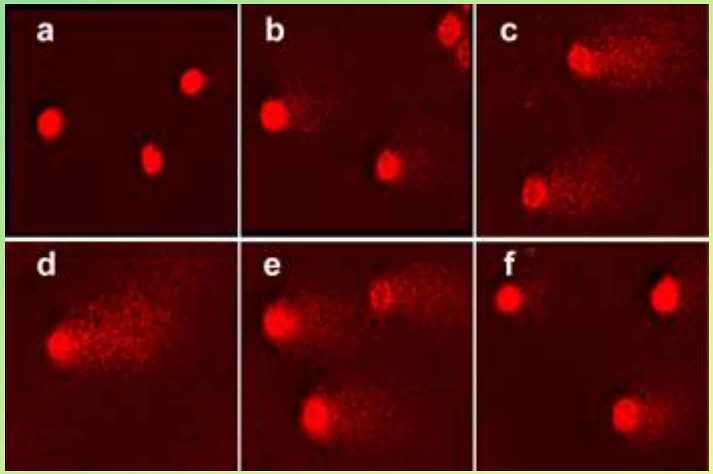
Microfabrication

Bio-Medical application

M.-C. Vozenin et al Clinical Oncol, 2019



Ultrafast Electron Irradiation effects on DNA



DMA damage and repair (In vitro)

N. Babayan et al, J. of Radiation Research, 2017.
N. Babayan et al, J. of Radiol & Rad. Therapy, 2018.
R. Aroutiounian et al, Molecular Citogenetics, 2019
A. Pepoyan et al, Annals of Microbiology, 2019
A. Osipov, Intern J Mol Sciences, 2020
G. Tsakanova, Biomedical Optics Express, 2020

Material Sciences

Time (s)

Time (s)	
10^{-6}	Thermal processes
10^{-7}	
10^{-8}	
10^{-9}	Secondary defects
10^{-10}	
10^{-13}	**Primary defects**
10^{-14}	
10^{-15}	
	Atoms collision
10^{-16}	
10^{-19}	Energy transfer to atoms
10^{-20}	

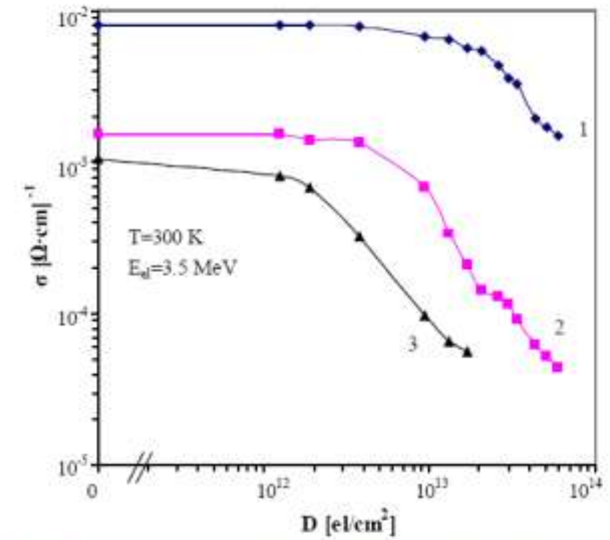
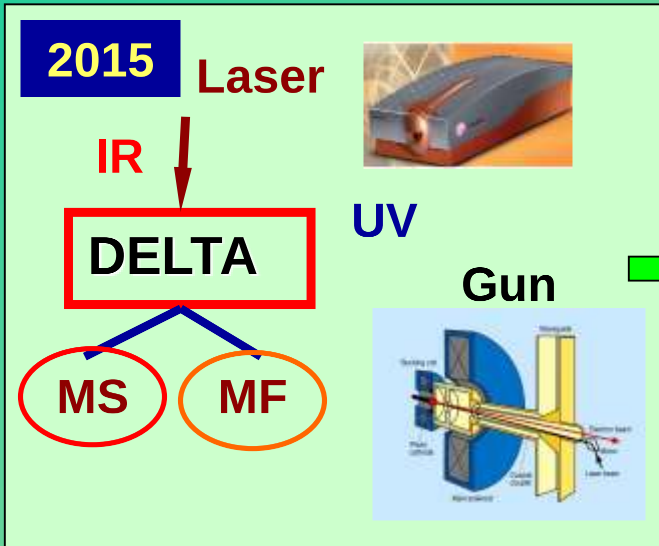


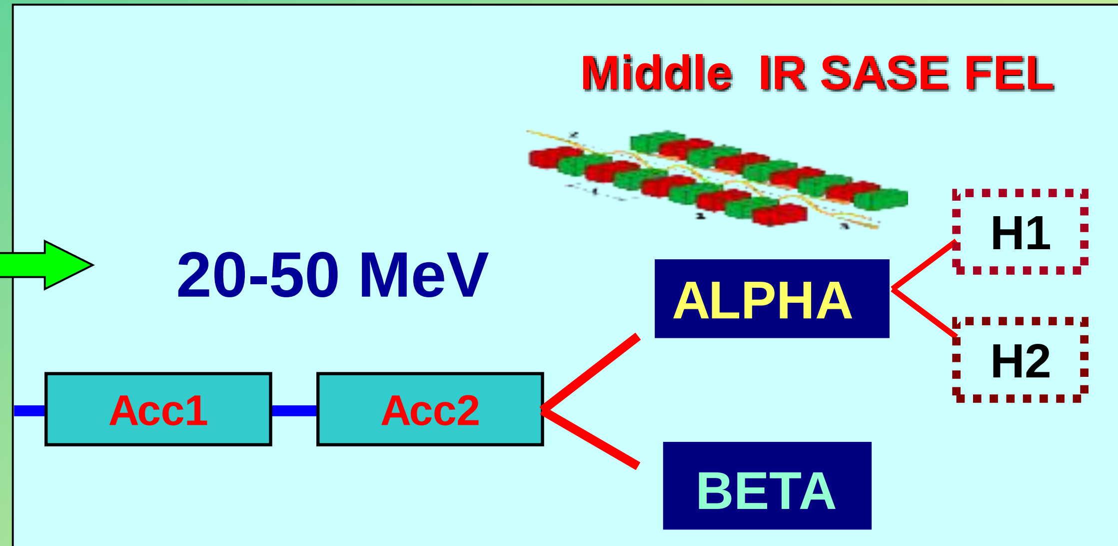
Figure 1. Silicon crystal (n-Si) electrical conductivity dose dependence by electron pico-second beam irradiation (energy 3.5 MeV). Samples specific resistivity: 1—100 Ω·cm, 2—700 Ω·cm, 3—950 Ω·cm. Maximum irradiation dose was 6 × 10^{13} el/cm^2.

Silicon-dielectric Structures.

H. Yeritsyan et al, JEM, 2017
V. Tsakanov et al, NIM, 2016
H. Yeritsyan et al, J Elec Mater, 2018
H. Yeritsyan et al, JMP, 2018
H. Yeritsyan et al, Rad Phys Chem, 2020

AREAL Highlights – 2018-2022



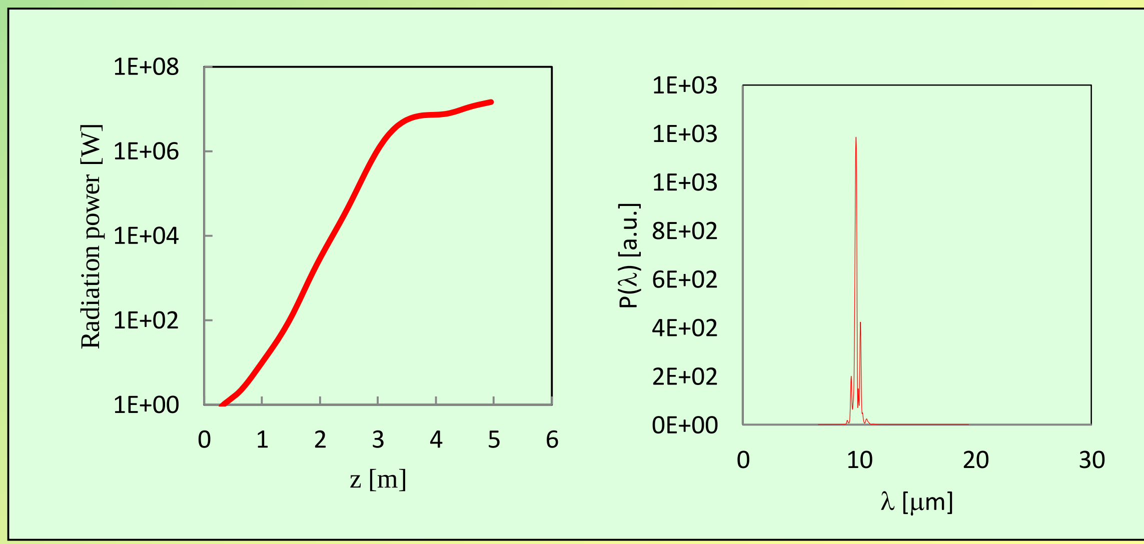


Middle IR FEL

Sat. length 2.1 – 3.2 m

Pulse energy 60-100 mJ

Power= 40 – 60 MW



Wavelength –2.5 - 30µm

Outlooks on R&D

- CANDLE full potential – 0.45 nm emittance → Isochronous Ring

- AREAL SASE FEL → Advanced Radiation Sources (Dielectric, Plasma …)

Thank You !