ADVANCED GENERATION OF THZ AND X-RAY BEAMS USING COMPACT ELECTRON ACCELERATOR

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("Advanced Generation of THz and X-ray" AGTaX collaboration)

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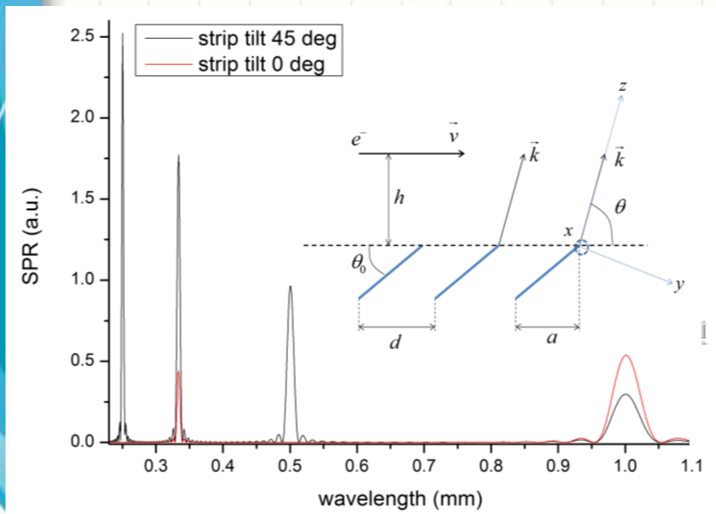
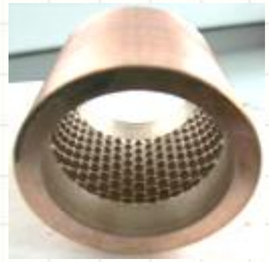
Channeling 2016, VIII AGTaX, 30 September, 2016

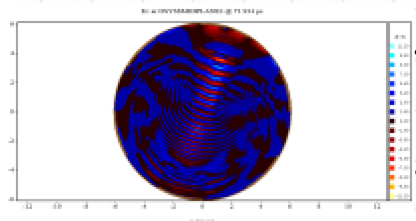
Outline

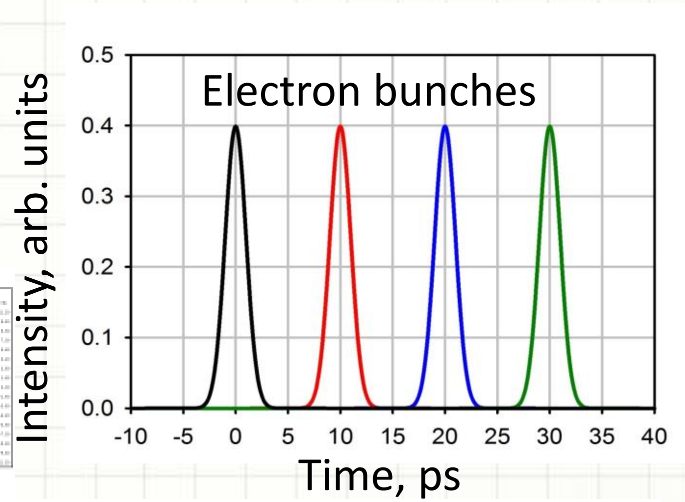
- FEL introduction
- THz FEL RF Gun laser system
- Pre-bunched beam dynamics
- Pre-bunched beam diagnostics
- THz resonator
- Conclusion, Plans, Schedule

Additional motivation





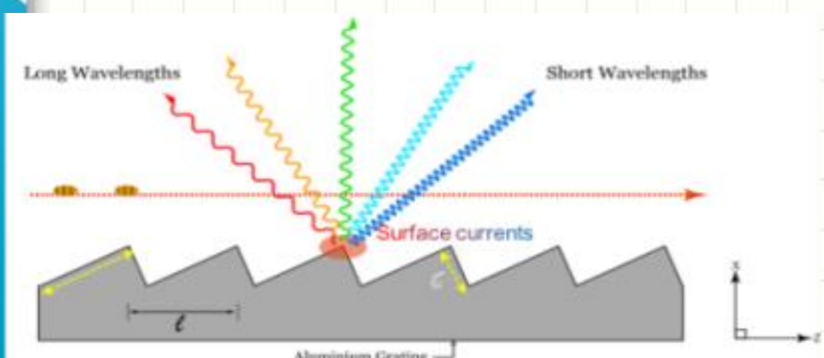




$$\frac{d^2W^s_{tot}}{d\omega d\Omega} = \frac{d^2W_{sing}}{d\omega d\Omega} N_e(1+(N_e-1)\,|\,f_l(\omega)\,|^2)$$

▼

$$\frac{d^2W^s_{tot}}{d\omega d\Omega} = \frac{d^2W_{sing}}{d\omega d\Omega} N_e\left(1+(N_e-1)\frac{\sin^2[\frac{N_b\omega\lambda_{RF}}{2\beta c}]}{\sin^2[\frac{\omega\lambda_{RF}}{2\beta c}]}\,|\,f_l(\omega)\,|^2\right)$$

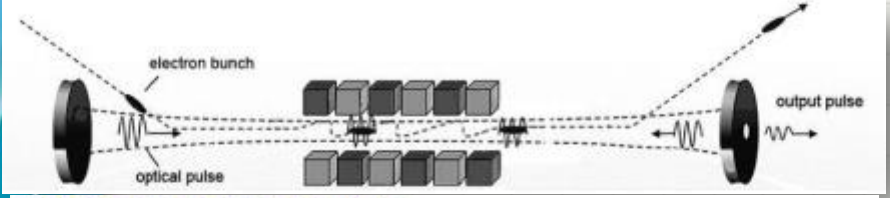


GTaX collaboration network

- "Advanced Generation of THz and X-ray" collaboration started in 2013.
- It brings together different communities working on the simulation, generation and experimental investigation of high-brightness THz and Compton X-ray beams.
- Based on several MoUs the following research strategy was agreed:
  - Construction of a stable and tunable laser system for RF gun development and THz radiation sources tests based on modern technology.
  - Build a broad collaborative network among leading institutions worldwide.
  - Develop state-of-the-art tunable coherent THz radiation sources on the basis of a compact (preferably table-top) accelerator.
- Collaboration experiments were started in 2015 at KEK LUCX.
- Seven collaboration meetings were held 2 times a year at almost every collaborator's institutions: KEK – 2013.03, RREPS13 (conference session) – 2013.09, MEPhI – 2014.05, SPbSU – 2014.10, Oxford – 2015.03, RREPS15 (conference session) – 2015.09 and KEK -2016.03.
- Future meetings are considered as follows: 2016.09 – Channeling2016 (conference session), 2017.02 – IUAC, 2017.09 – Wuhan University.
- Collaboration supported by:
  - Leverhulme Trust Network "Advanced Research on Generation of THz and X-ray Radiation" (IN 2015 012)
  - JSPS KAKENHI grant numbers 23226020 and 24654076 (Finished April 2016)
  - JSPS – RFBS bi-lateral research program

Pre-bunched THz FEL introduction

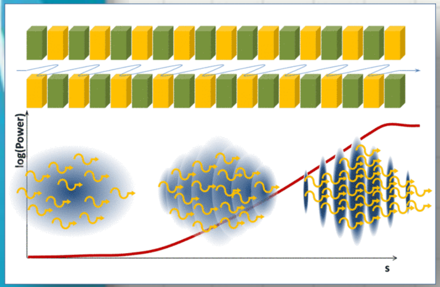
Madey, John, "Stimulated emission of bremsstrahlung in a periodic magnetic field". J. Appl. Phys. 42, 1906 (1971)
Madey, John, Stimulated emission of radiation in periodically deflected electron beam, US Patent 38 22 410,1974

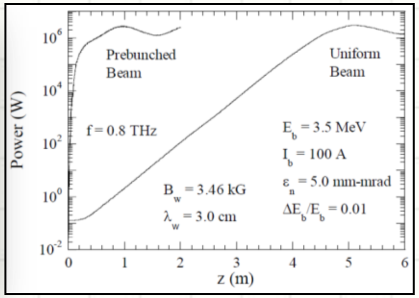


Wavelength of FEL radiation:

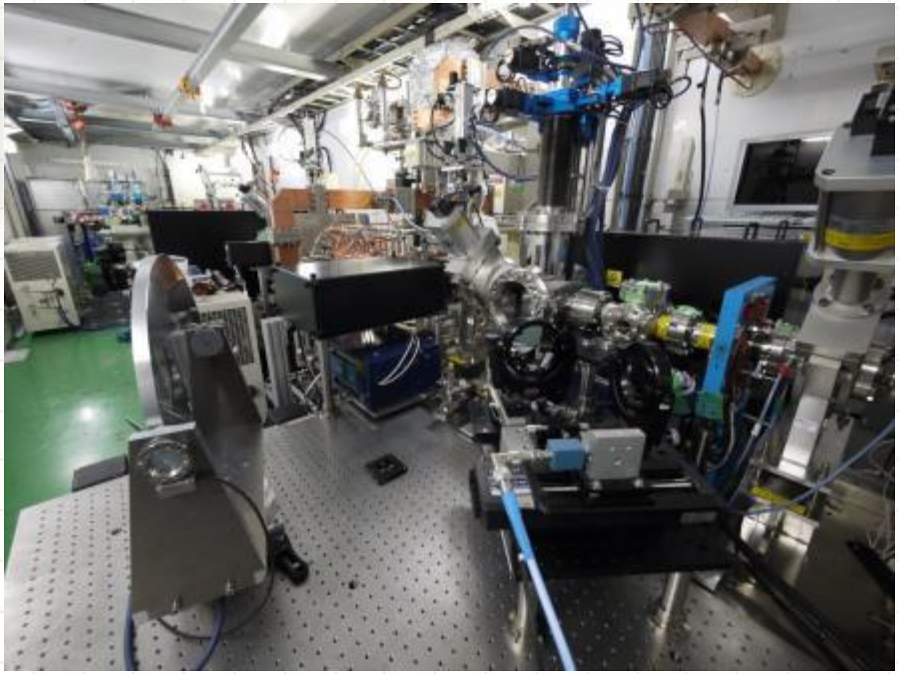
$$\lambda(cm^{-1}) = \frac{\lambda_w}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

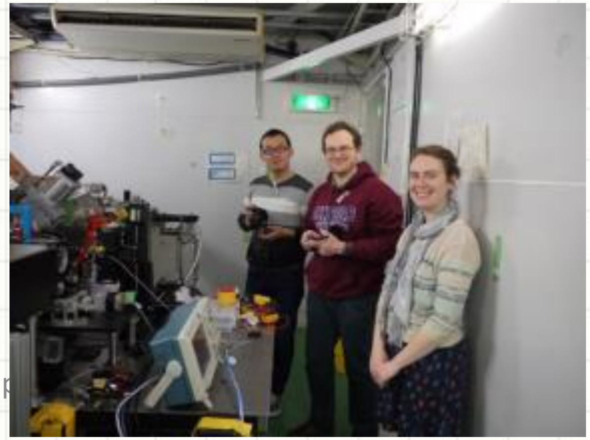
λ_w – period of undulator (cm)
$\gamma = E/E_0$ – relativistic factor
$K = 0.93\, B_0\, \lambda_w$
B – magnetic field in undulator (T)



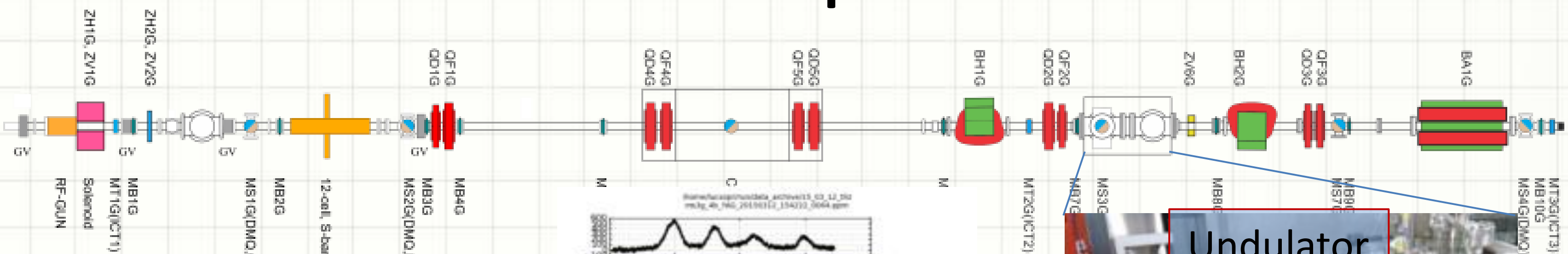


Simulation of Henry Freund

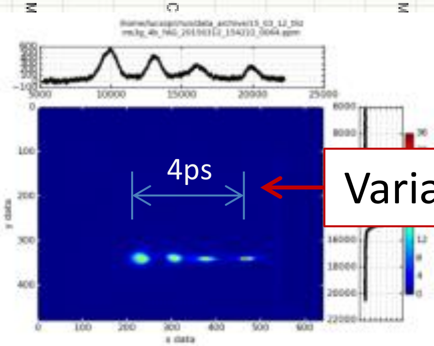


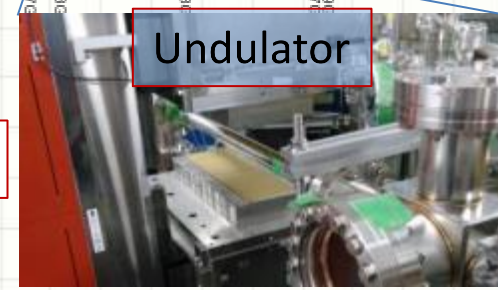


LUCX beamline and operation modes

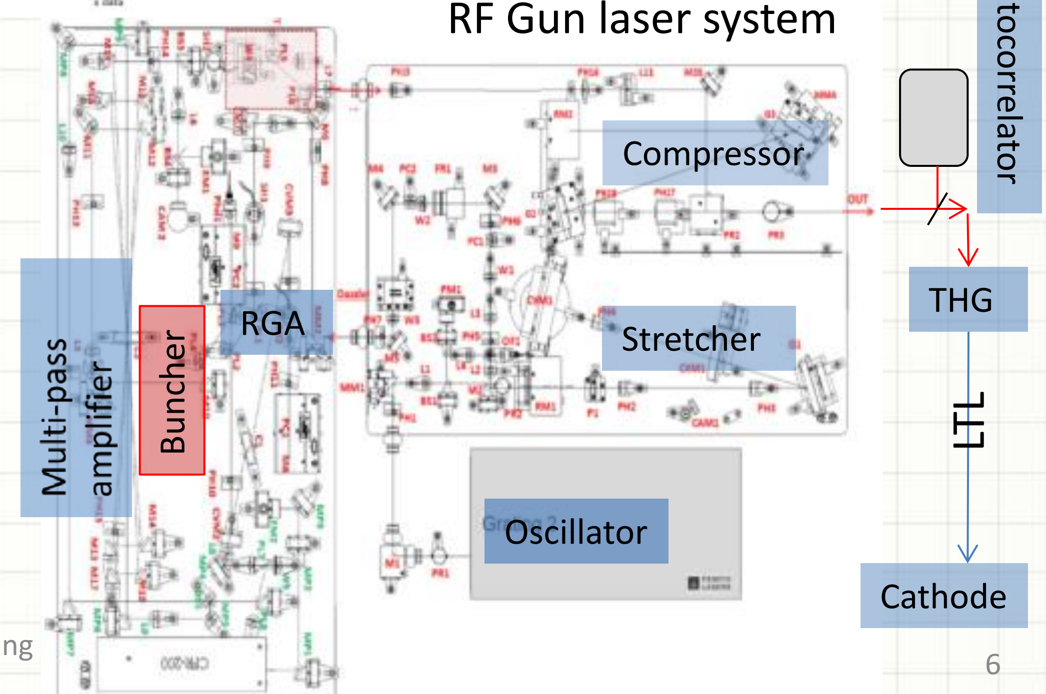


"Femtosecond mode"
- Ti:Sa laser
- e-bunch rms length ~100fs
- e-bunch charge < 100pC
- Single bunch train, Micro-bunching 4-16 (4 is confirmed)
- Typical Rep. rate 3.13 Hz
- Experiments: THz program



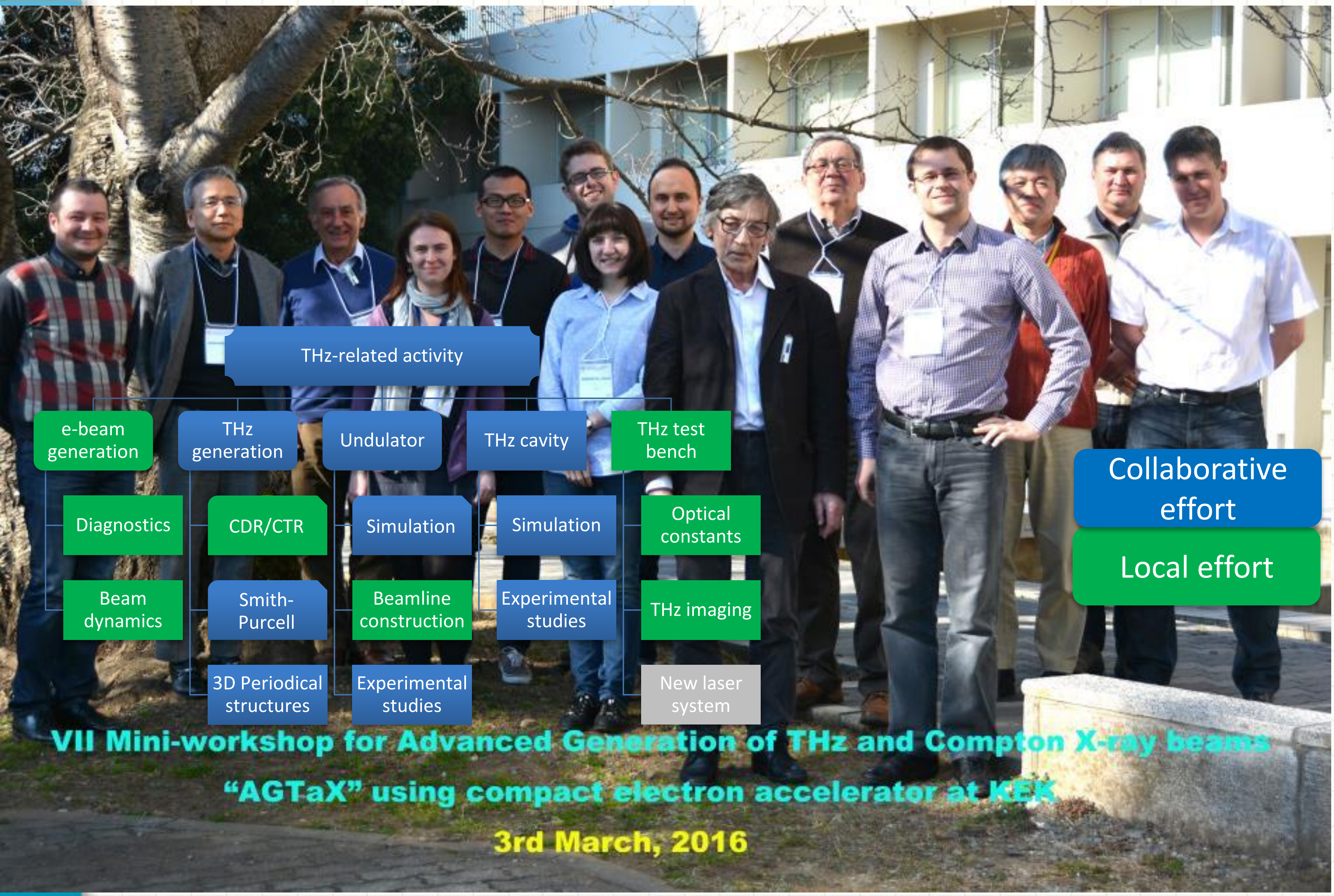


- Ce_2Te cathode Q.E. measurements
  - Confirmed to be same as of ps and fs laser – 0.4%
- Ce_2Te cathode response time
  - First step experiment to confirm < 250fs response
  - Present measurements shows ~ 160fs response



"Picosecond mode"
- Q-switch Nd:YAG laser
- e-bunch rms length ~10ps
- e-bunch charge < 0.5 nC
- Multi-bunch train 2- few 10^3
- Max Rep. rate 12.5 Hz
- Experiments: Compton, CDR

Channeling


THz-related activity
e-beam generation
THz generation
Undulator
THz cavity
THz test bench
Diagnostics
CDR/CTR
Simulation
Simulation
Optical constants
Beam dynamics
Smith-Purcell
Beamline construction
Experimental studies
THz imaging
3D Periodical structures
Experimental studies
New laser system
Collaborative effort
Local effort
VII Mini-workshop for Advanced Generation of THz and Compton X-ray beams
“AGTaX” using compact electron accelerator at KEK
3rd March, 2016

Conclusion & Summary

- Following electron beam parameters @ THz station were confirmed:
  - Energy ~ 8.5 MeV
  - Energy spread < 1 % rms
  - Transverse rms beam size @ THz station ~ 500x500 um
  - Bunch length ~ 250 fs (4 micro-bunch average)
  - Number of micro-bunches – 4
  - Minimum micro-bunch time separation ~ 250 fs
  - Micro-train charge (4 micro-bunches) ~ 100 pC

Resources

- Skype
  - Aryshev Alexander : alarkek
- E-mails
  - Aryshev Alexander : alar@post.kek.jp

Thank you for your attention