ELECTRON BEAM SHAPING FOR HIGH EFFICIENCY ACCELERATION AT THE AWA FACILITY

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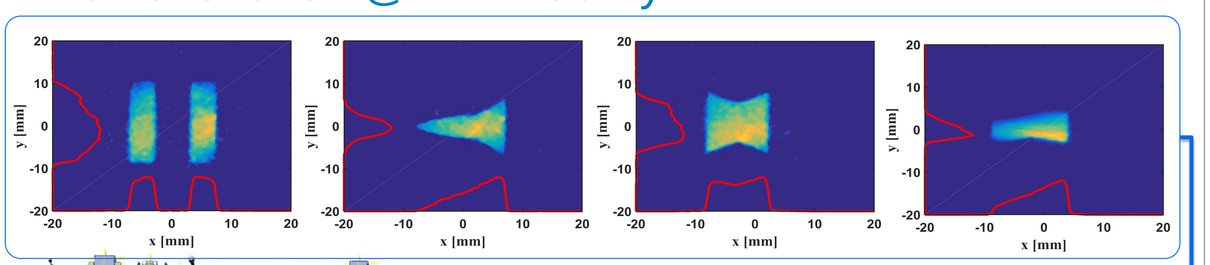
ABSTRACT

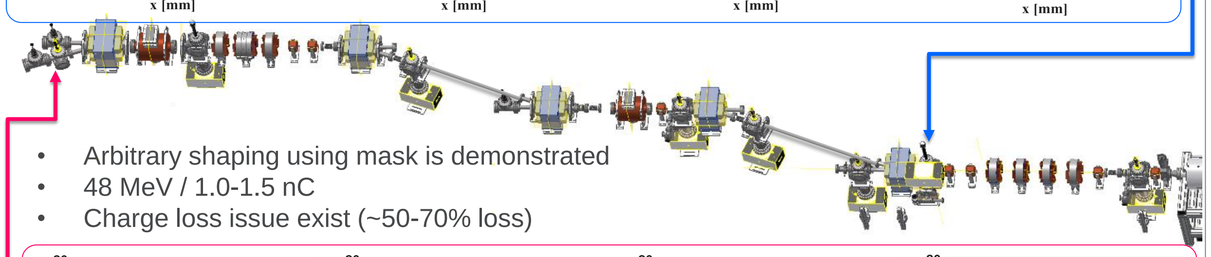
A central challenge for next generation accelerator facilities (Linear Colliders and FELs) is to operate at high wall plug efficiency. However, the fraction of energy that can be transfer from the accelerating fields to the charge particle bunch is limited by beam loading. This is true for advanced acceleration schemes, Structure Wakefield Acceleration (SWFA), Plasma Wakefield Acceleration (PWFA) and Laser Wakefield Acceleration (LWFA) as well as conventional acceleration. In the typical case of a beam with a longitudinally Gaussian shape, heavy beam loading can induce an unacceptably high energy spread on the bunch. On the other hand, if the beam shape is chosen correctly, then the energy spread can be controlled.

At the Argonne Wakefield Accelerator (AWA) facility, we are exploring several bunch shaping methods (emittance exchange based, laser controlled and deflecting cavities method) to address this issue. Plans to demonstrate high efficiency acceleration of a longitudinally shaped electron beam in a SWFA scheme called Two-Beam acceleration is shown below.

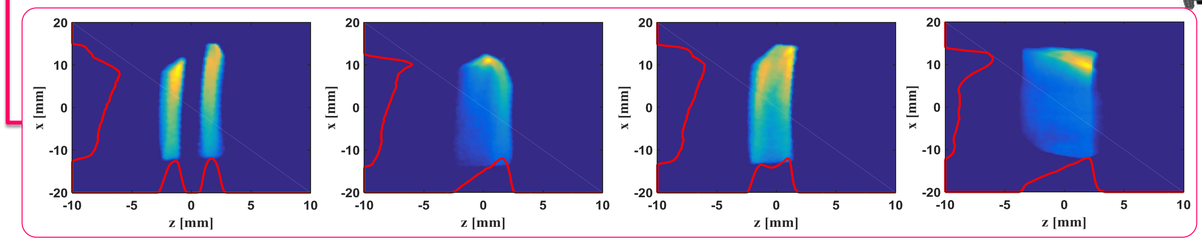
EMITTANCE EXCHANGE BASED SHAPING

Demonstration @ AWA facility



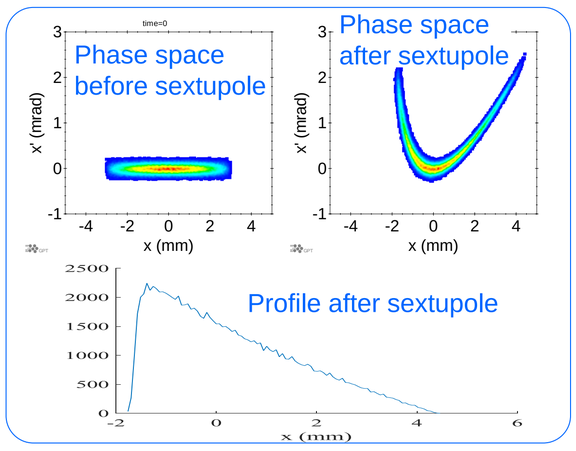


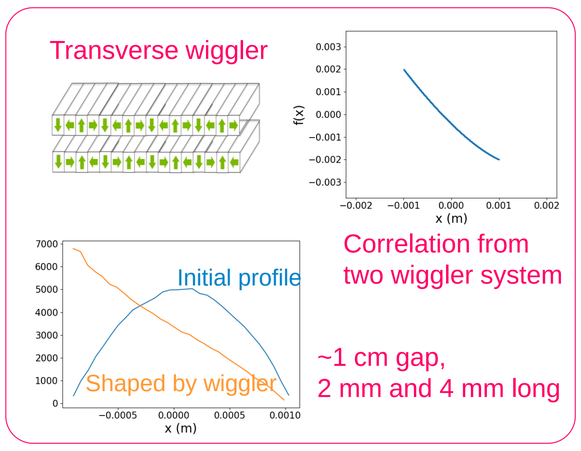
- Arbitrary shaping using mask is demonstrated
- 48 MeV / 1.0-1.5 nC
- Charge loss issue exist (~50-70% loss)



Transmission improvement

Triangle is achievable without loss!



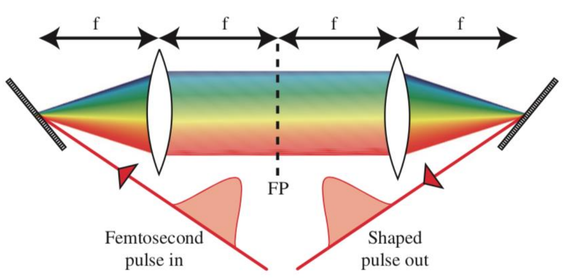


Correlation from two wiggler system

~1 cm gap,
2 mm and 4 mm long

LASER CONTROLLED SHAPING

SLM based shaping concept



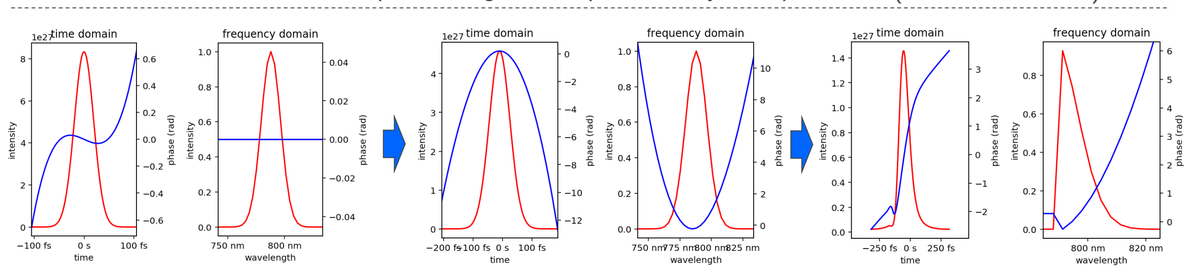
- Spatial light modulator can shape beam's spectral profile
- This can be applied for temporal shaping of the laser
- Laser controlled shaping work is on-going at AWA facility

Numerical test

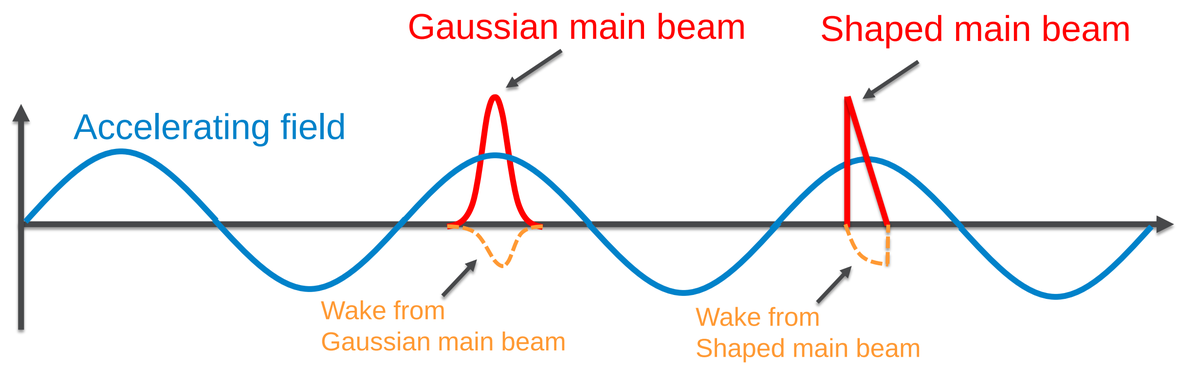
Gaussian pulse with a flat phase
$\lambda_0 = 788$nm, FWHM 26nm

Introduce the chirp
(2cm BK7 glass, chirp not exactly linear)

Shape spectrally with a digital mask
(Heaviside function)



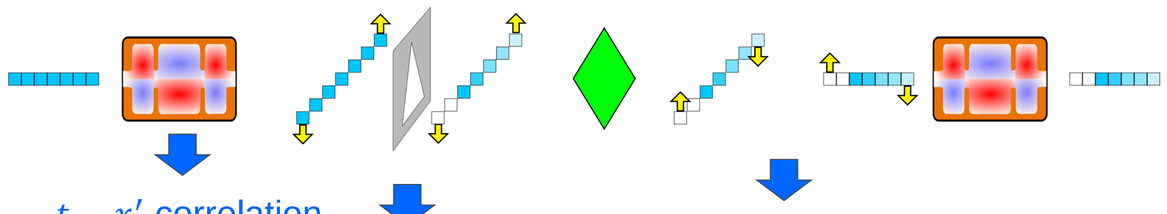
CONCEPT OF MAIN BEAM BEAM-LOADING CONTROL



- Wakefield from the main beam effects on the energy gain
- Appropriate shaping enables uniform acceleration

DEFLECTING CAVITY BASED SHAPING

Principle of deflecting cavity based method



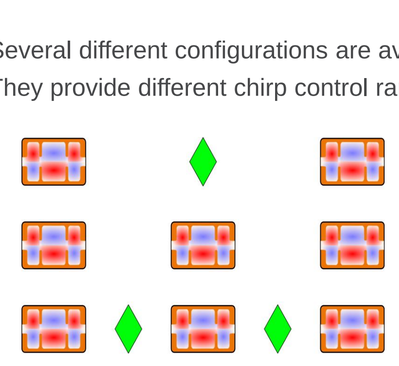
$t - x'$ correlation

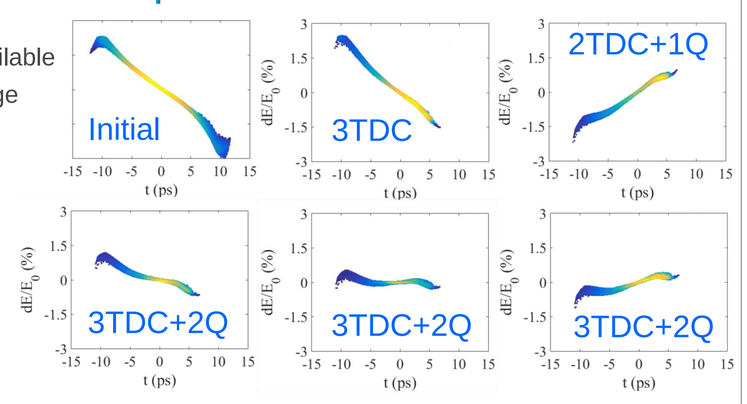
Shaping t due to the correlation

Quad and another cavity removes remained $t - x'$ correlation

Other configuration and chirp control

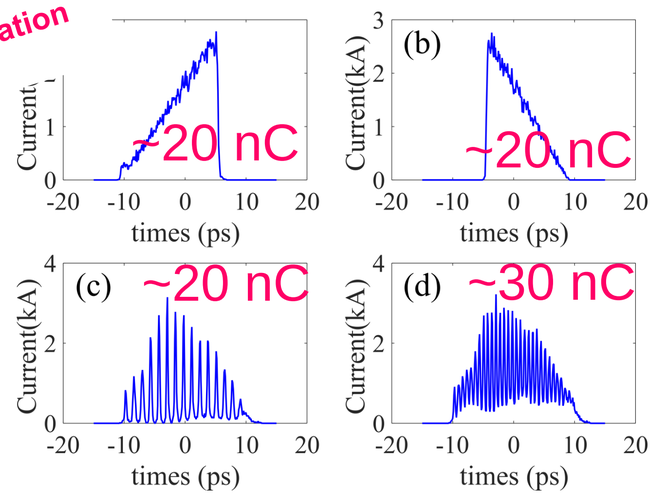
- Several different configurations are available
- They provide different chirp control range





Unique high charge shaping capability

Start-to-end simulation with 60 nC beam



CSR-free shaping enables high charge shaping

Spcaing: 0.7 ps
Microbunch length: 0.4 ps FWHM
30 bunches

S2E SIMULATION FOR MAIN BEAM SHAPING

- Start-to-end simulation is done using the deflecting cavity based method
- Single mode wake function is convoluted to the simulated profile
- The concept beautifully works