MOPG50

DEFLECTING CAVITY DYNAMICS FOR TIME-RESOLVED MACHINE STUDIES

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Abstract

Radio frequency deflectors are widely used for time-resolved electron beam energy, emittance and radiation profile measurements in modern free electron laser facilities. In this paper, we present the beam dynamics aspects of the deflecting cavity of SXFEL user facility, which is located at the exit of the undulator. With a targeted time resolution around 10 fs, it is expected to be an important tool for time-resolved commissioning and machine studies for SXFEL user facility.

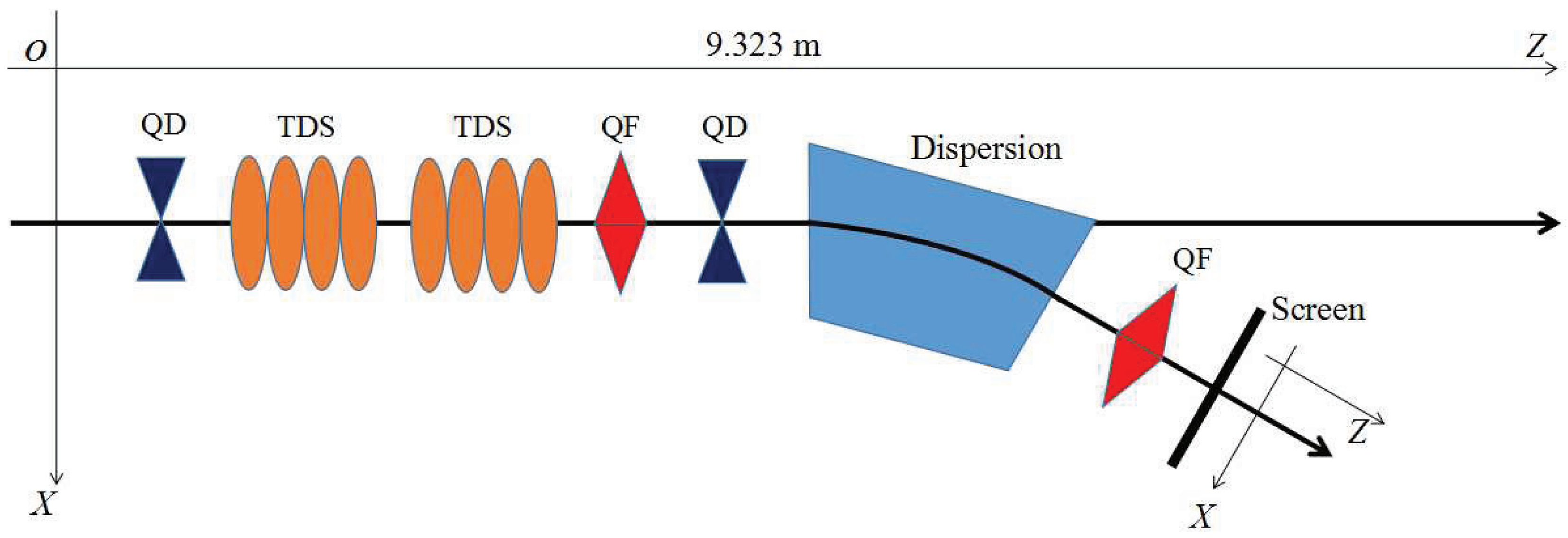
Introduction

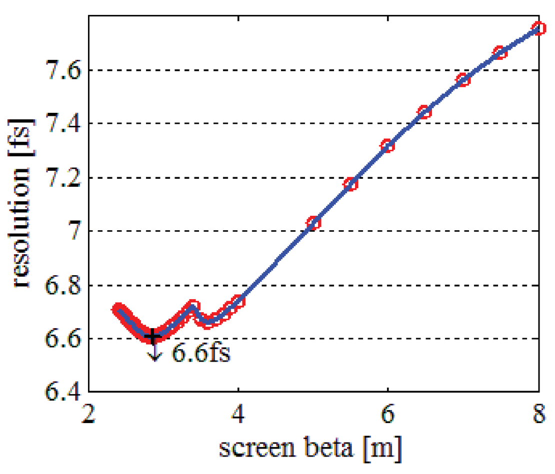
Free electron laser (FEL) in the X-ray spectral region is a highly fruitful field ranging from ultra-fast scale probe to molecular biology, and from material science to medical science. Currently, the first X-ray FEL (8.8 nm) facility in China driven by 840 MeV LINAC is under construction at Shanghai, namely SXFEL test facility [1-2]. A soft X-ray user facility [3] has been proposed on the basis of SXFEL test facility. With a straightforward beam energy upgrade to 1.5 GeV, the FEL wavelength will extend to 2.0 nm and fully cover the water-window region [3]. In order to guarantee the FEL lasing performance at short wavelength, besides cascading HGHG [4], EEHG [5] and PEHG [6], a SASE [7] undulator line which consists of in-vacuum undulator and the insertion is also raised up.

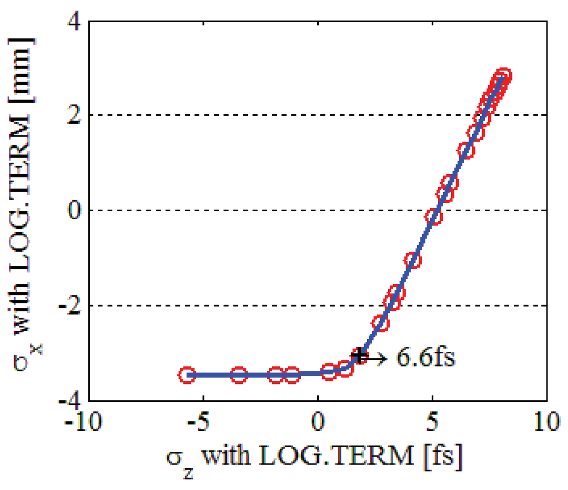
For such an ultra-short bunch required for excellent FEL performance, one of the great challenges is the measurement and diagnosis with high temporal resolution. Up to now, many techniques have been developed, including zero RF phasing and streak camera. Transverse RF deflecting cavity is introduced to diagnose longitudinal profile of the electron bunch and FEL radiation, which is capable of resolving the temporal structure as short as sub-fs level under the circumstance of high deflecting voltage and frequency [8]. Since this method can effectively convert time-correlated longitudinal profile into the transverse profile, thus the bunch could be revealed and analysed in more detail. In terms of high efficiency and resolution, this technique would become key diagnostic system in the future. Therefore, a pair of X-band RF deflectors is planned at the exit of the undulator section of SXFEL user facility.

Simulation Results

Layout of the TDS beamline downstream the undulator section



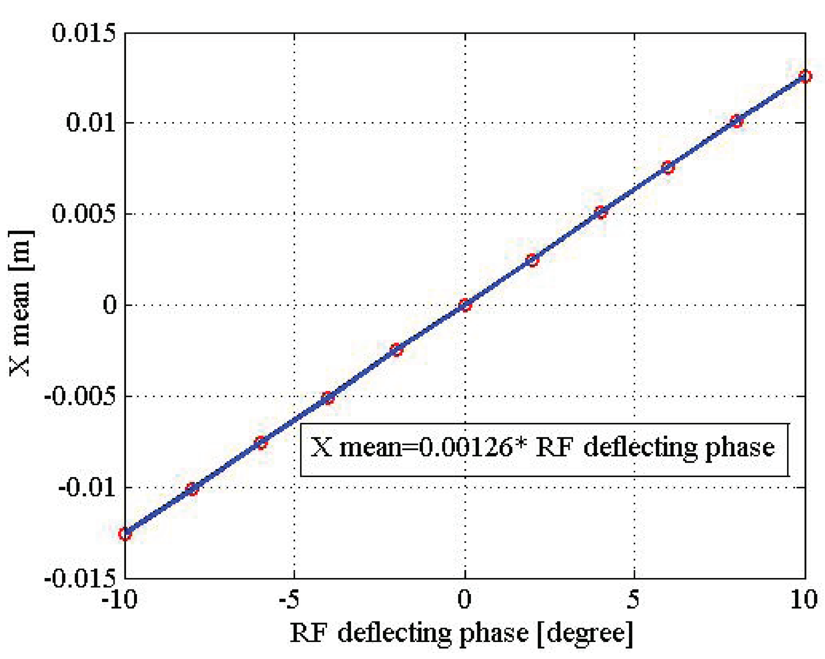




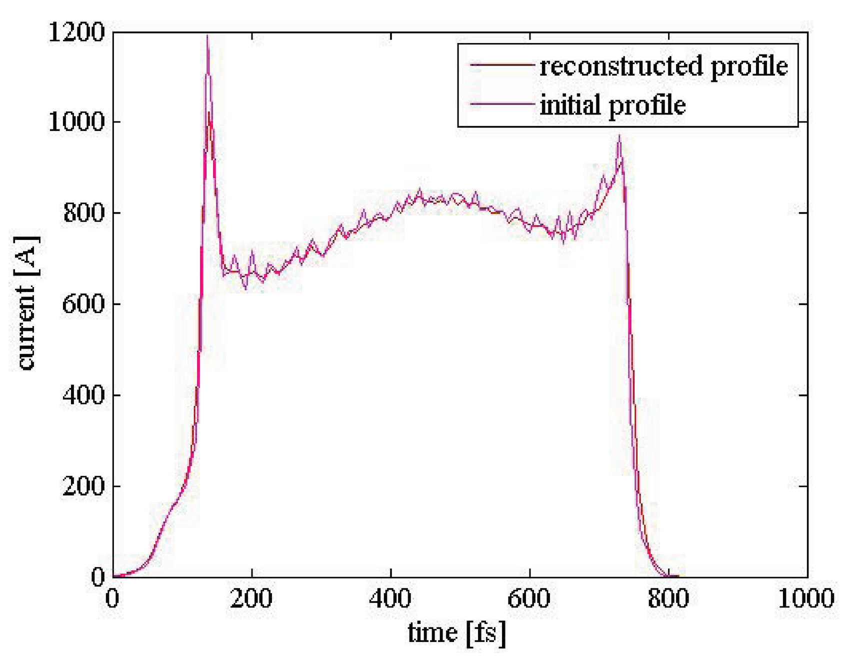
Main parameters of TDS and optimized beamline

RF deflecting frequency	f	11.424	GHz
RF deflector voltage	V_0	10	MV
RF deflector length	L	1	m
RF deflector number		2	
Nominal beam size	σ_{x0}	31.5	μm
Beam size with TDS on	σ_x	971.6	μm
Beta at TDS	β_d	8.8	m
Beta at screen	β_s	2.9	m
Phase advance	$\Delta\varphi$	79	$degree$
Normalized emittance	ε_n	1.015	μm
RMS bunch length	σ_z	55.797	μm

Resolution optimization &simulation results
minimum resolution approaches nearly 6.6 fs



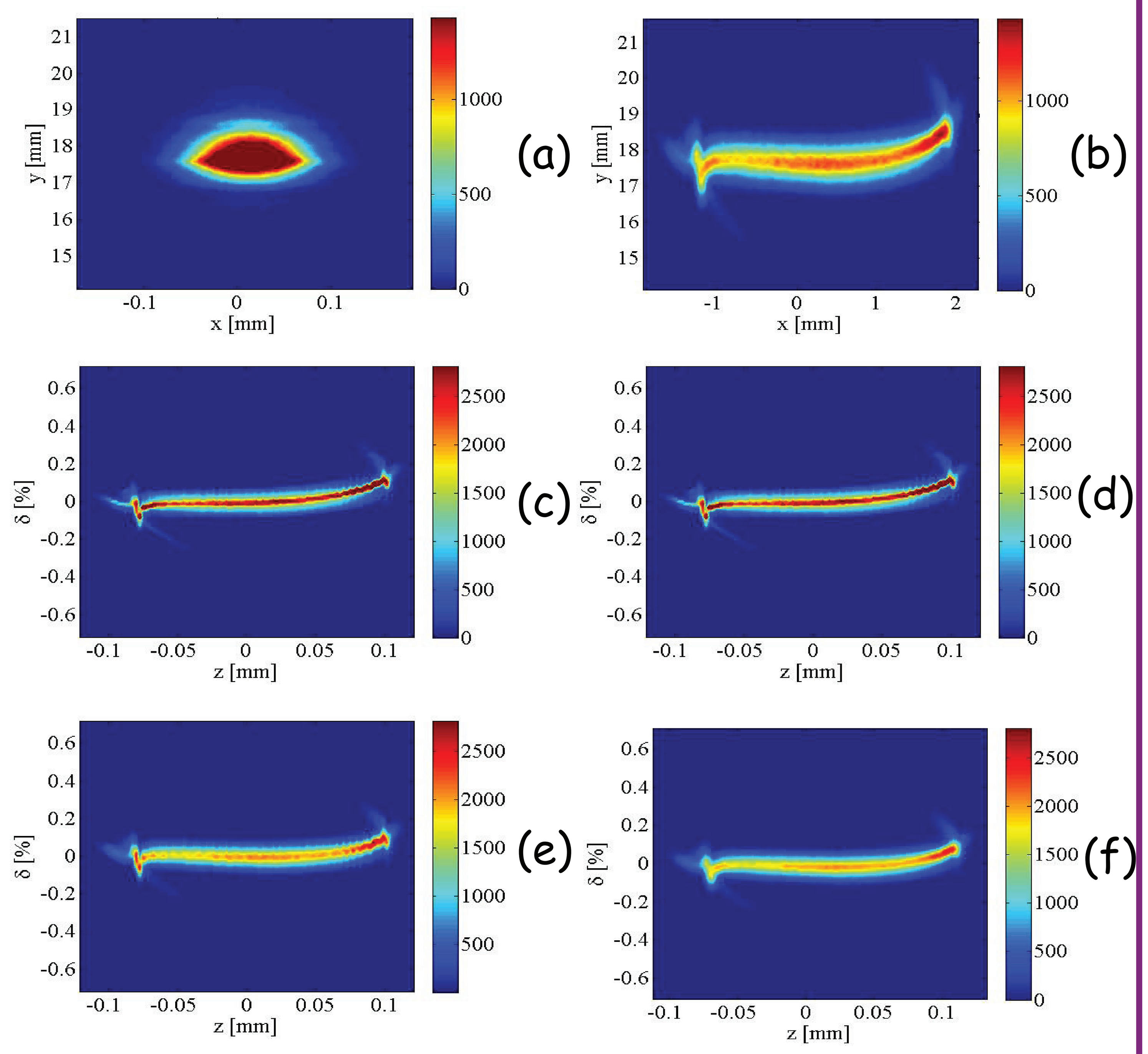
TDS calibration at the observation screen at the end of beamline. The horizontal beam centre shows a dependence on RF deflecting phase with red circle points, the blue line represents the linear fit.



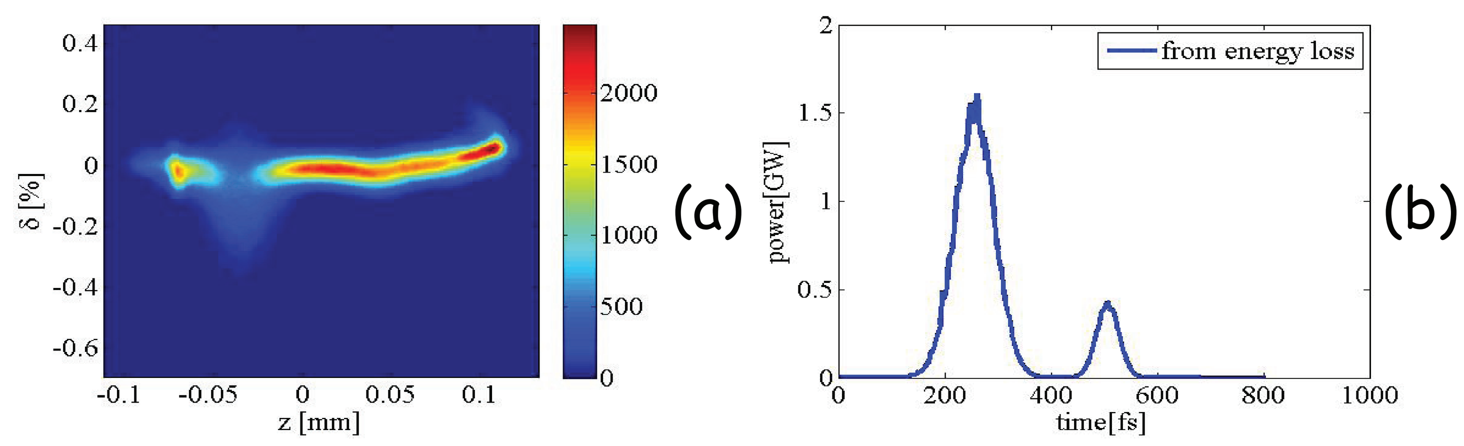
Comparison between the tracked current profile (pink curve) and the reconstructed profile (red curve).

$$D = K * 360^\circ * f / (\beta * c)$$

the slope of linear fit is 0.00126m/degree,.
frequency f=11.424GHz and relativistic velocity equal to one
Equation can calculate the deflecting parameter as 17.273.



Simulated screen beam images with TDS off (a) and TDS on (b). Simulated longitudinal phase space along the beamline: (c) the original phase space, (d) in front of the RF deflecting cavity, (e) in front of the dipole magnet, (f) reconstructed phase space at the screen.



FEL temporal profile reconstruction. The simulated results are shown in: (a) Reconstructed FEL lasing downstream the TDS, (b) Reconstructed X-ray pulse duration and shape.

Conclusion & Outlook

The schematic layout of TDS beamline for SXFEL user facility was described and optimized in this paper. With the installation of X-band RF deflecting cavities, measurements of the longitudinal electron beam phase space and the X-ray FEL pulse profile can be carried out. Simulation results confirm that the beamline allows one to measure the electron bunch with a time resolution of 6.6 fs, which can be further enhanced by the transverse gradient undulator compensation [11]. In addition, besides the capabilities shown in this paper, other potential applications, for instance, studies of micro-bunching instability and slice energy spread can be carried out in the future.

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