Coherent Terahertz Radiation Monitors for Multiple Spectral Bands

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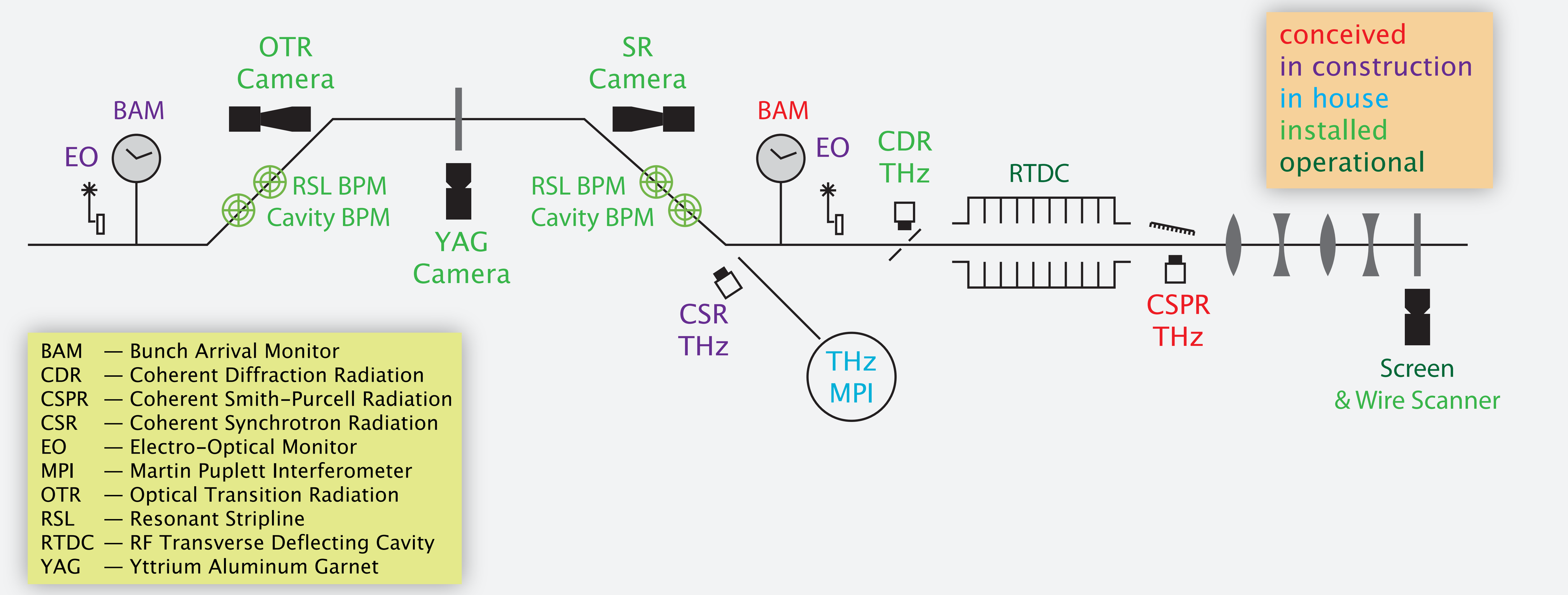
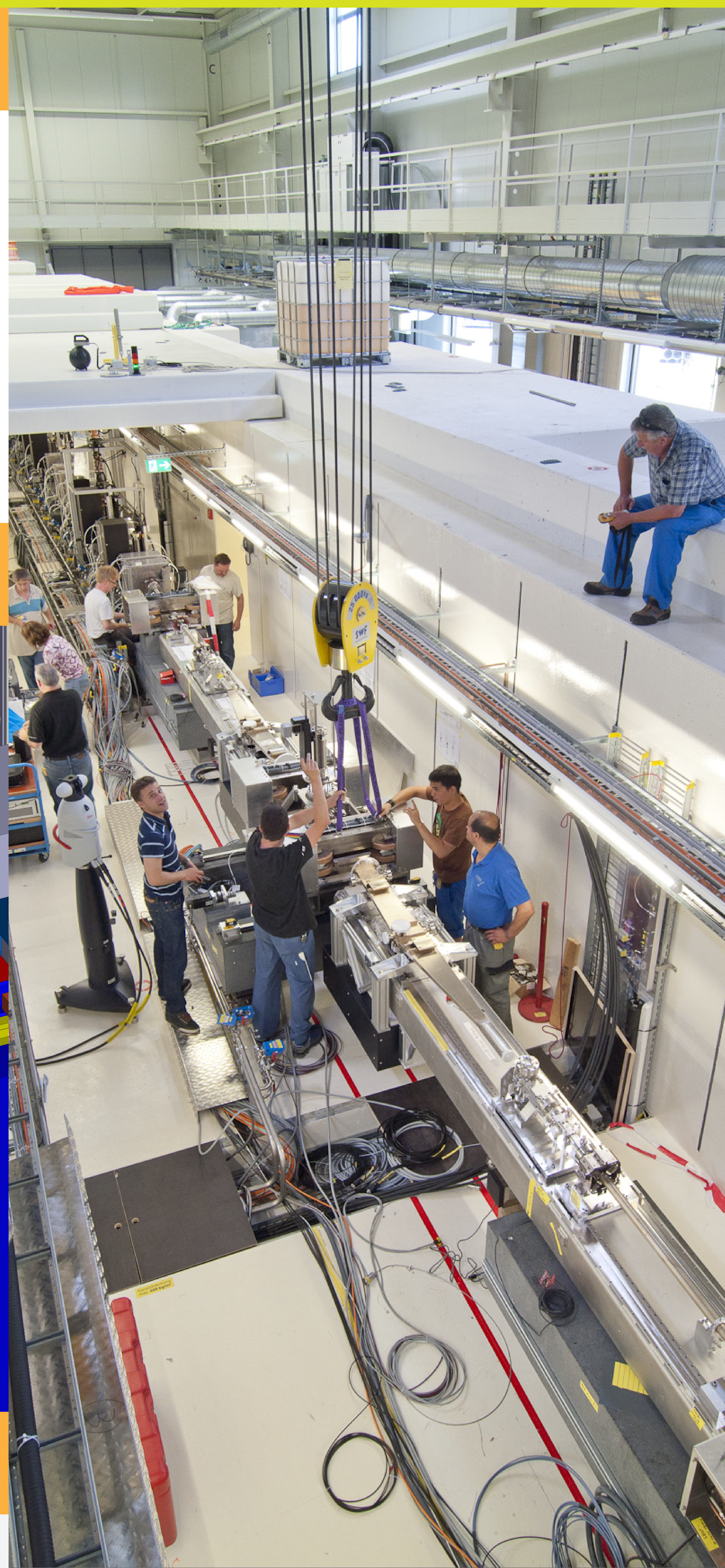


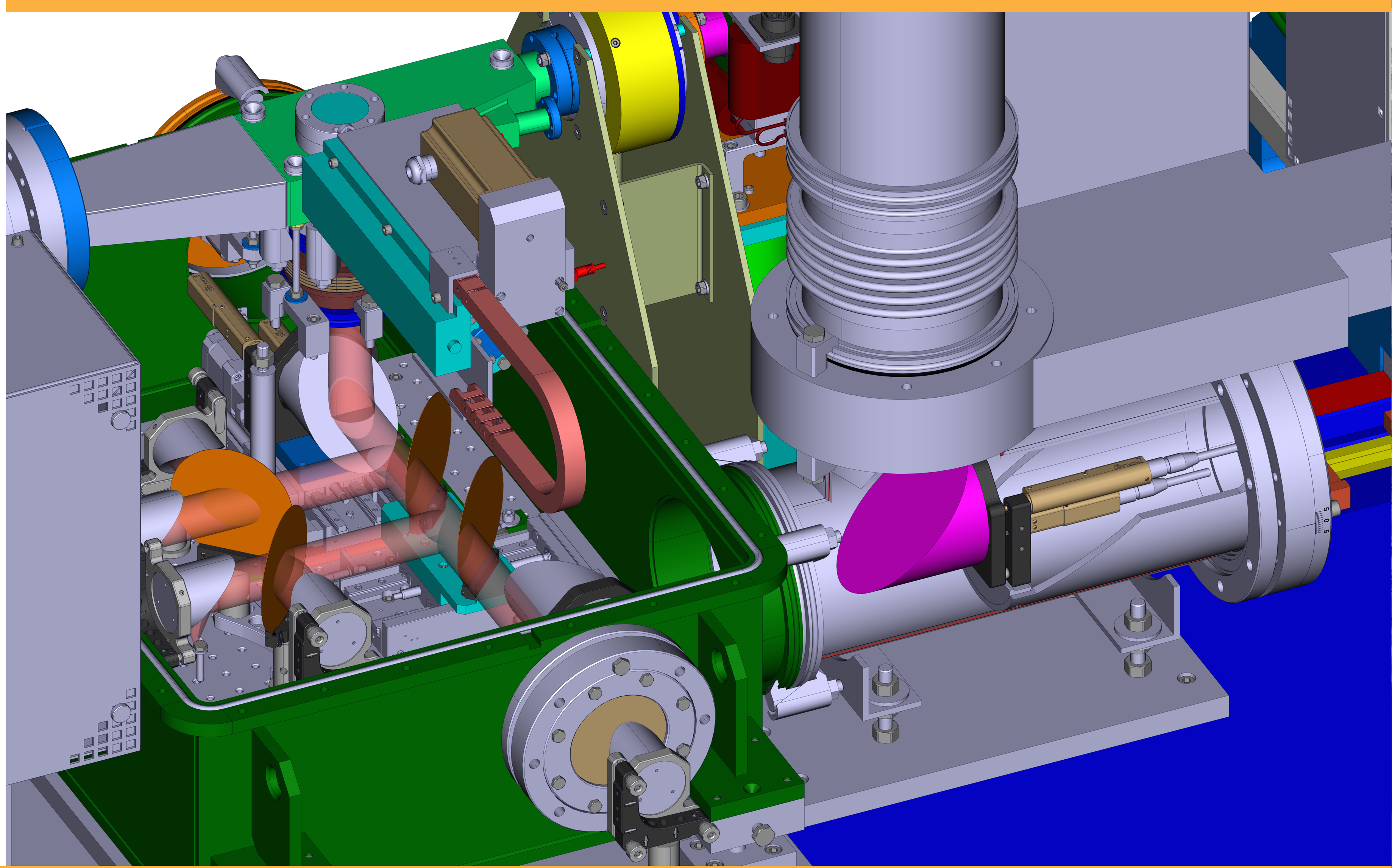
BC1 Diagnostics

As a preparation for the SwissFEL free electron laser, Paul Scherrer Institut is currently commissioning the SwissFEL Injector Test Facility (SITF). Electron bunches have been accelerated up to an energy of 130MeV, and a magnetic chicane that will be used to compress the bunches longitudinally has recently been installed.
This bunch compressor can be adjusted to arbitrary angles between 0 and 5 degrees to study details of the bunch compression dynamics. The vacuum chamber follows the motion of the central magnets, and the instrumentation has to be adjusted accordingly. The figure to the left shows an overview of the diagnostics that have been installed and of those that will be installed in the near future.

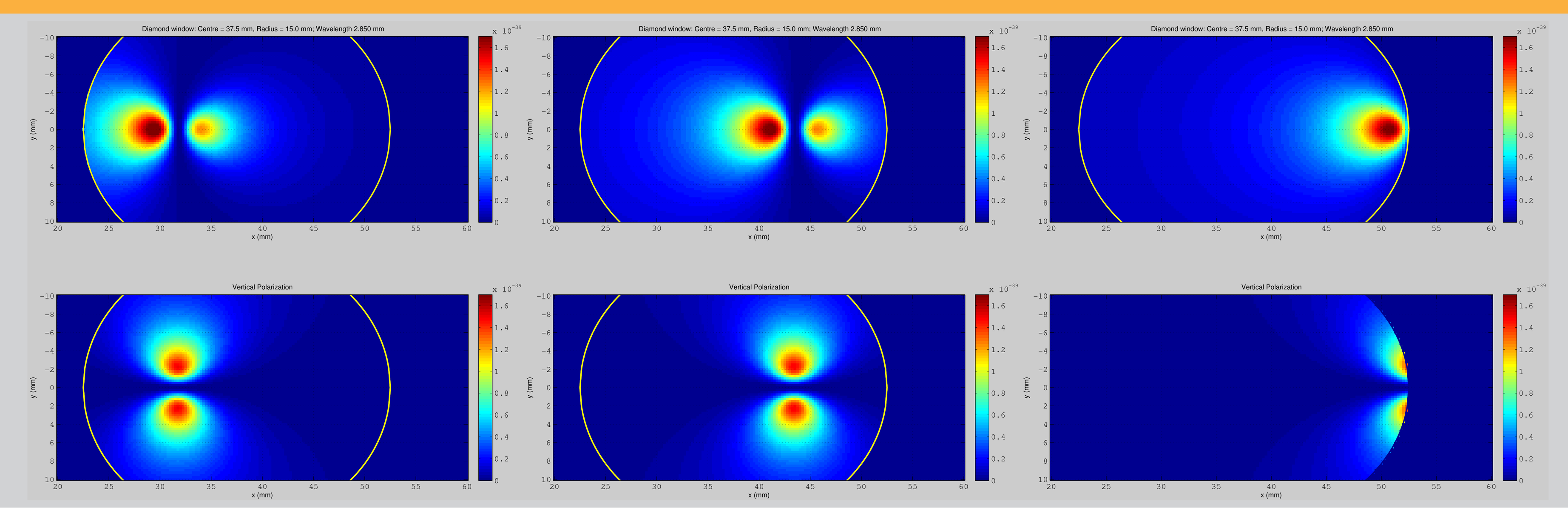


Many methods exist to measure the longitudinal phase space of electron bunches, and several of these will be installed in the SITF.Direct measurements of the bunch distribution can be performed with an RF transverse deflecting cavity (RTDC) and with electro-optical (EO) monitors. Both an RTDC and an EO monitor are foreseen for the SITF.
Bunches longer than a picosecond can also be measured with a streak camera. Due to the limitations of bunch lengths, such a device is not installed in the SITF.
Measurements in the frequency domain have the advantage that they typically become easier as the bunch length becomes so short that it approaches optical wavelengths. A Martin-Puplett interferometer will be installed in the SITF to record the autocorrelation of coherent synchrotron radiation.
However, since phase information is lost in the detection of the radiation, additional information has to be used to reconstruct the bunch shape unambiguously.
Finally, the integration of the pulse energy of coherent radiation in a certain frequency range can be used to assess the bunch length. While such bunching monitors do not give an absolute measurement of peak current or pulse length, they allow for a fairly simple set-up that can be used at all times to monitor the stability of the bunch compression process.
The signal as a function of bunch length can be cross-calibrated by using the RF transverse deflecting cavity and then used for constant on-line monitoring or feedbacks.

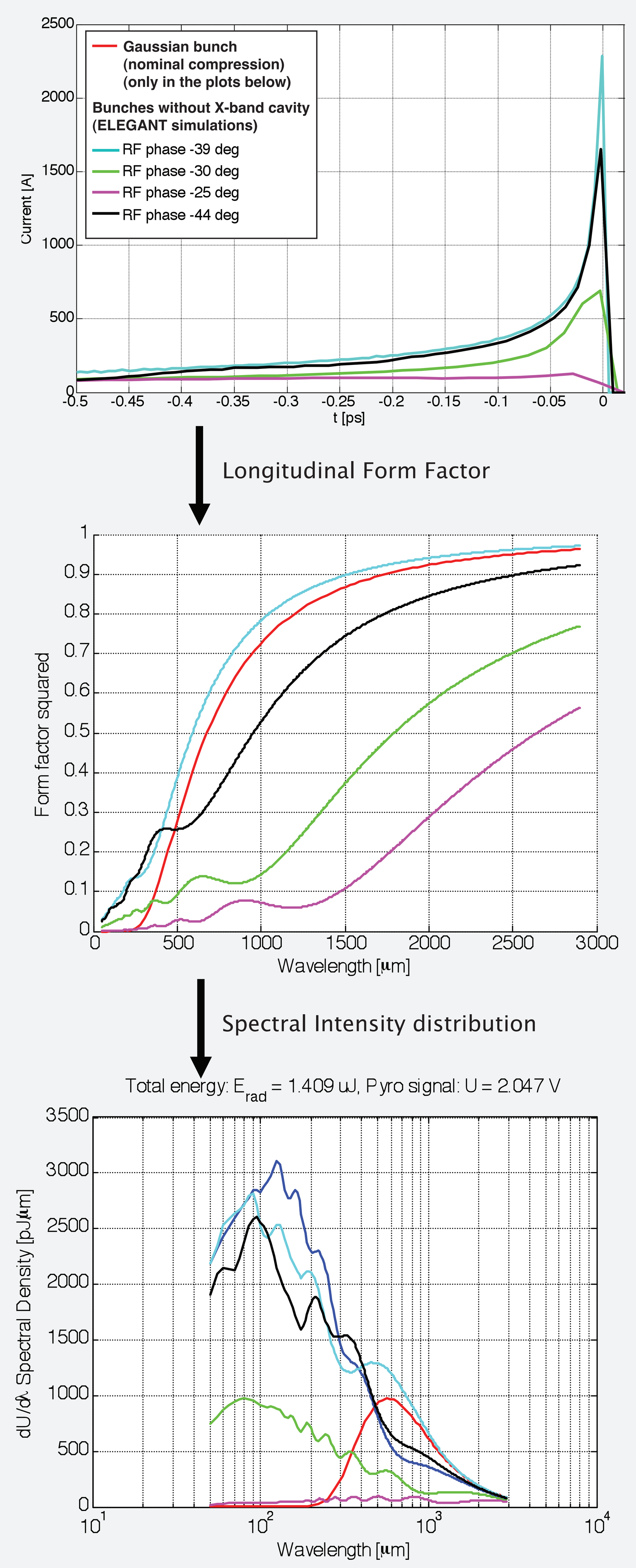
Coherent Synchrotron Radiation Monitor



Modeling of Synchrotron Radiation



The synchrotron radiation distribution varies with bunch compressor angle. To assess these variations, the distribution on the vacuum window has been modeled.
The system has been optimized for the nominal angle of 4.1°, but can be used between 3 and 5 degrees.
The calibration to the RF deflecting cavity of signal as a function of bunch length will be done for different angles.

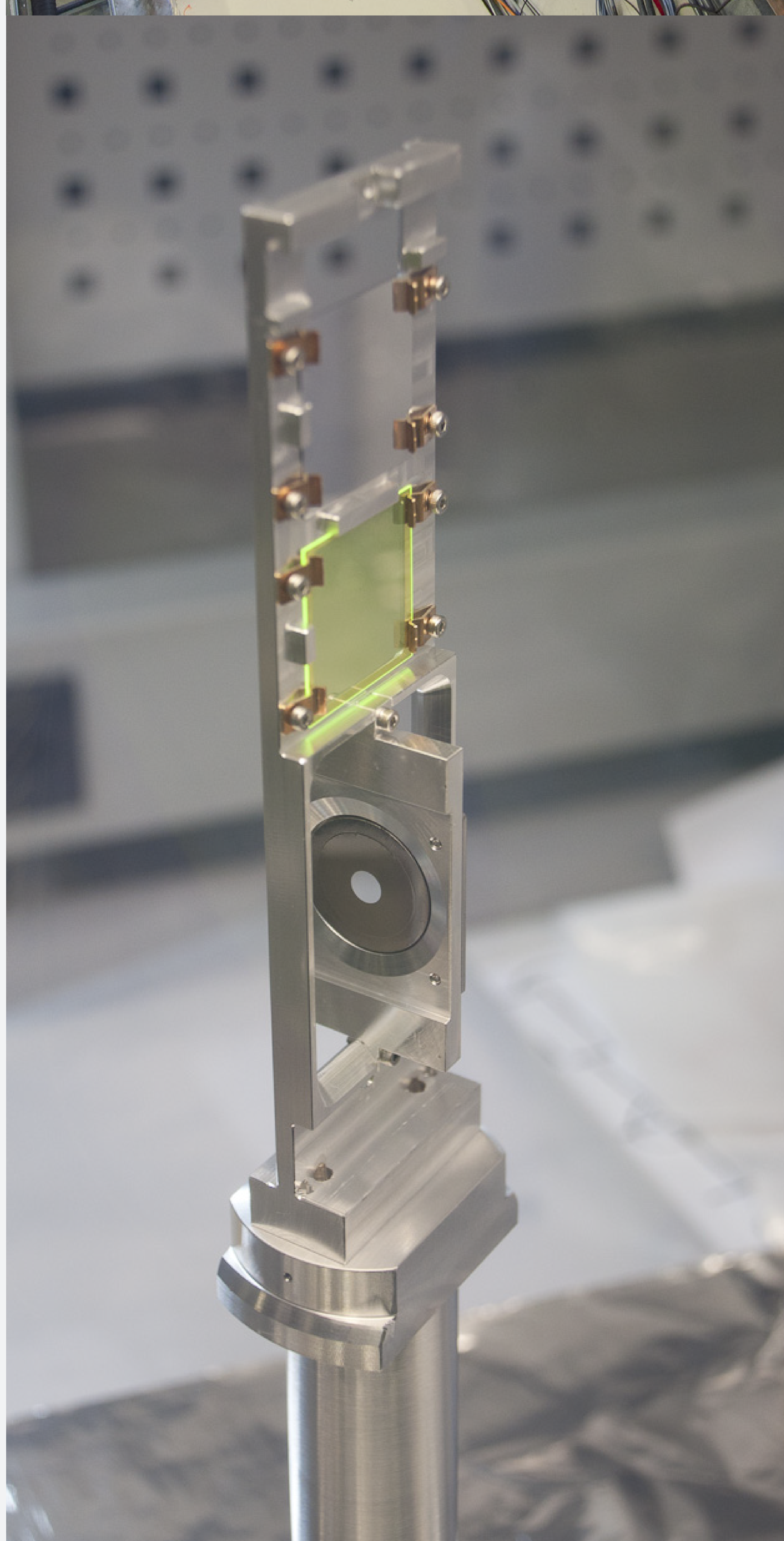


To evaluate the relevant spectral content of the coherent radiation, simulations of the bunch shape have been performed:
The electron bunch was simulated with the code ELEGANT both with and without the X-band accelerating structure.
From the distribution in the fourth bunch compressor dipole, the longitudinal form factor was calculated.
The coherent synchrotron radiation was then calculated with MATLAB.

Comparison of CSR and CDR

Comparison of coherent synchrotron radiation (CSR) and coherent diffraction radiation (CDR) as a source for the SwissFEL bunching monitor.

CSR	CDR
⊕ CSR is a non-invasive THz source, which is always available	⊖ To produce CDR, an iris needs to be inserted into the beam, which may degrade the beam quality
⊖ The mirrors that collect the light need to be re-aligned after a change in bunch compressor angle	⊕ The alignment is independent of the bunch compressor
⊖ The emitted radiation depends on the magnet current	⊕ The signal is independent of the setting of the bunch compressor
⊖ The radiation that reaches the detector is primarily emitted at the entrance of the fourth dipole, before the bunch compression process is complete	⊕ The radiation is emitted by the fully compressed beam
⊕ A halo of the electron bunch produces the same radiation	⊖ A halo may produce transition radiation, which could be more intense than the CDR
⊖ The system relies on a complicated setup to couple the beam out of the vacuum chamber	⊕ A very simple setup can be used



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