

# IP082: Towards Time-Resolved Ultrafast Low Energy Electron Microscopy



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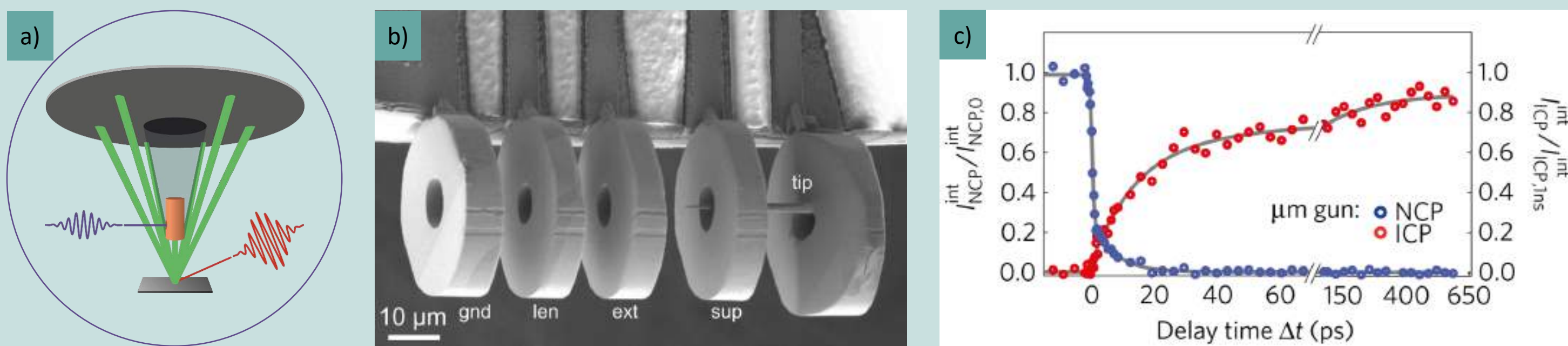
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**1 Overview:** Time-resolved measurements of surface dynamics allow the investigation of surface phenomena in highly non-equilibrium states [1]. With the emergence of laser systems with ultrashort pulse lengths, a variety of techniques was established. The most important methods can be distinguished by their sensitivity to charge or structural dynamics as well as the imaging of real or reciprocal space:

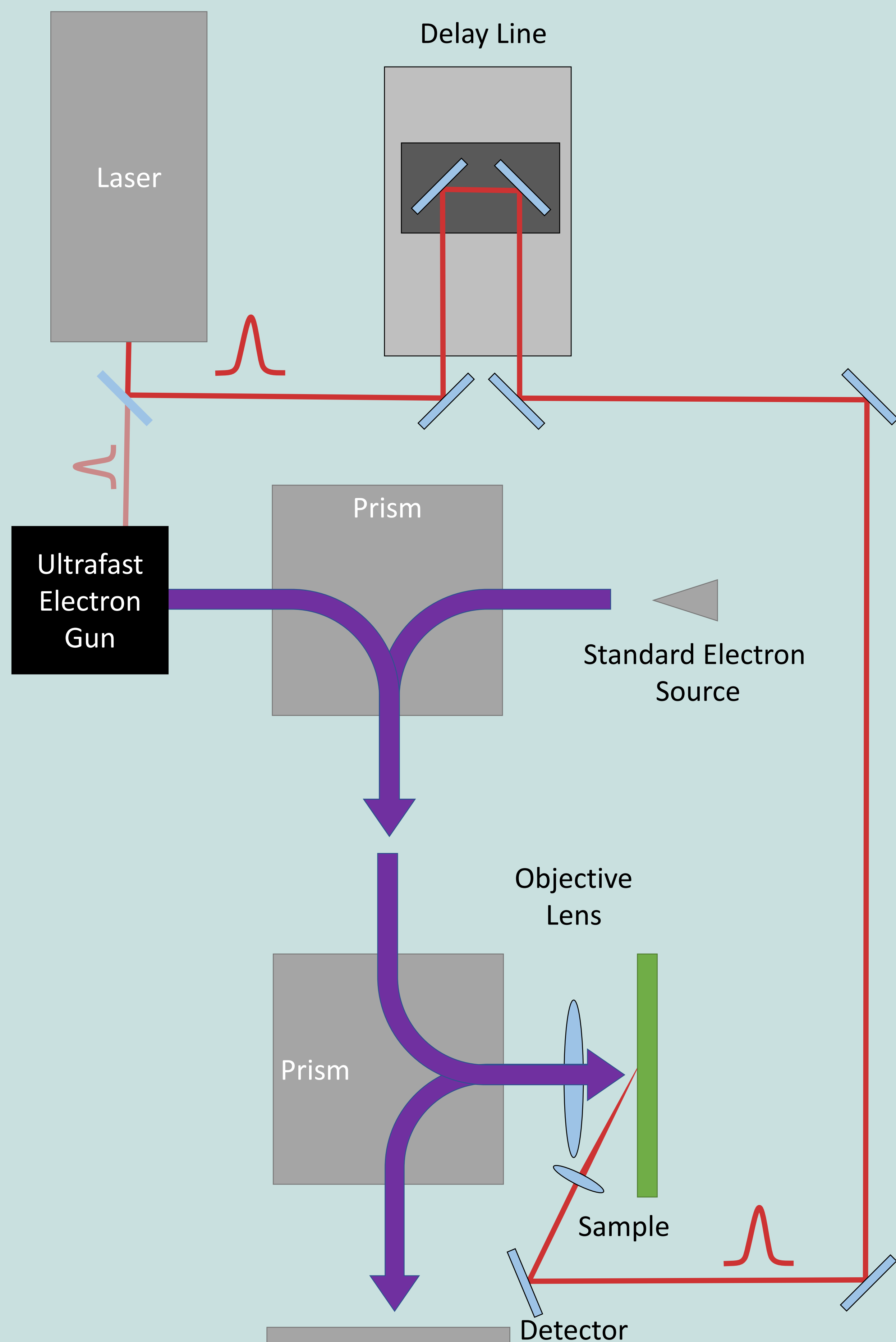
	Reciprocal	Real Space
Charge	trARPES [2]	trPEEM [3]/trSTM [4]
Structure	trRHEED [5]/ULEED [6]	(ULEEM) [7]

**2 Time-Resolved Electron Scattering for Surface Dynamics:** Previous efforts of our group established ultrafast LEED as a measurement technique to investigate structural surface dynamics of periodic structures.

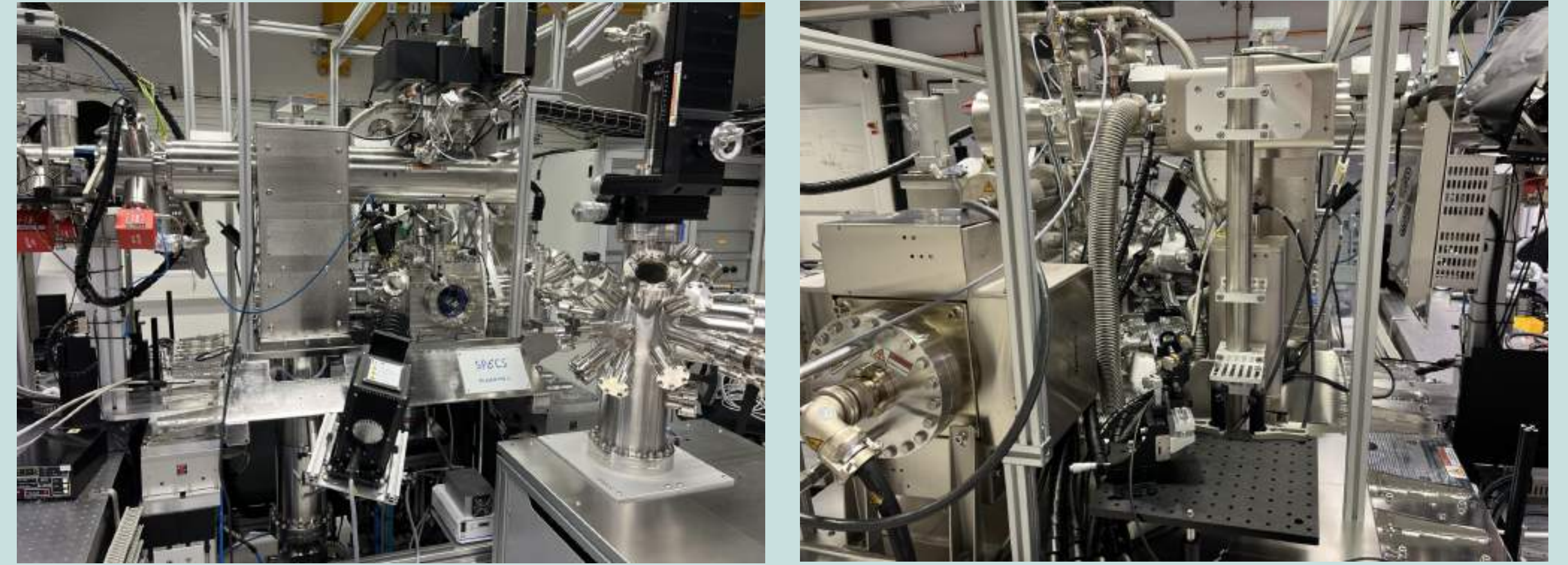


a) ULEED experimental scheme with pump (red) and probe (purple) laser pulse. b) Miniaturized electron gun: In order to achieve the highest time resolution, the electron source needs to be as close to the sample as possible. The miniaturization allows for a smaller shadow of the gun on the diffraction image [8]. c) Investigated transition from the nearly-commensurate to the incommensurate charge-density-wave state in TaS<sub>2</sub> with a time resolution of 1.4 ps [9].

**3 Concept:** Real space structural dynamics can be studied by already existing experiments, such as ultrafast transmission electron microscopy [10]. However, until now, there is no established technique for the investigation of real space surface structural dynamics. In order to fill this gap, we designed an instrument analogous to Wan et al. proposed in [6] with two electron guns: the standard LEEM gun and a gun modified for laser-triggered electron emission.



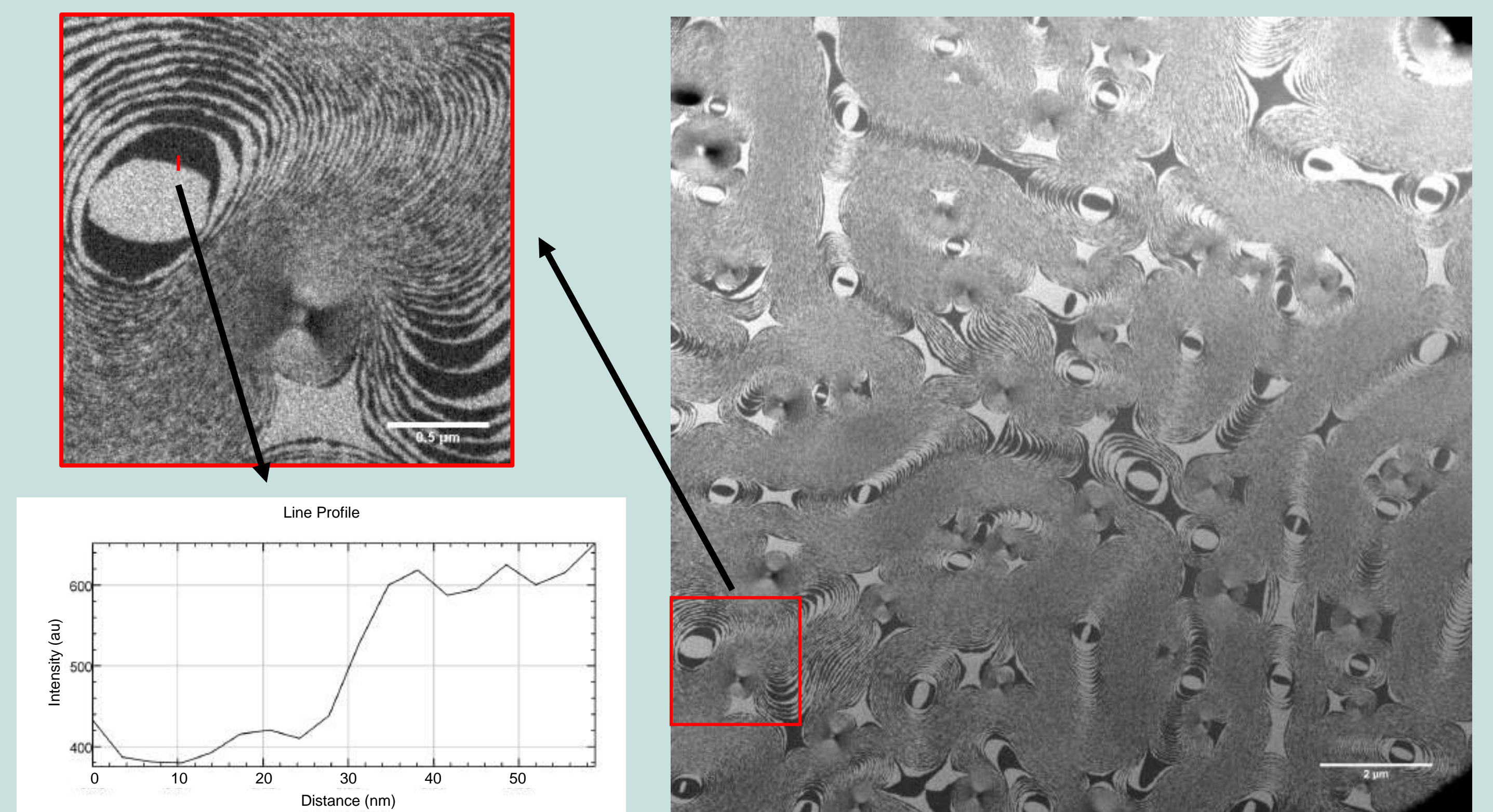
**4** After the design phase, the instrument was installed in August 2022:



**5 Estimated Parameters:** The instrument is based on a SPECS FE-LEEM/PEEM P90 equipped with an additional prism and an ultrafast electron gun. Based on the standard instrument and our previous experience with ultrafast electron guns, we estimate the following machine parameters:

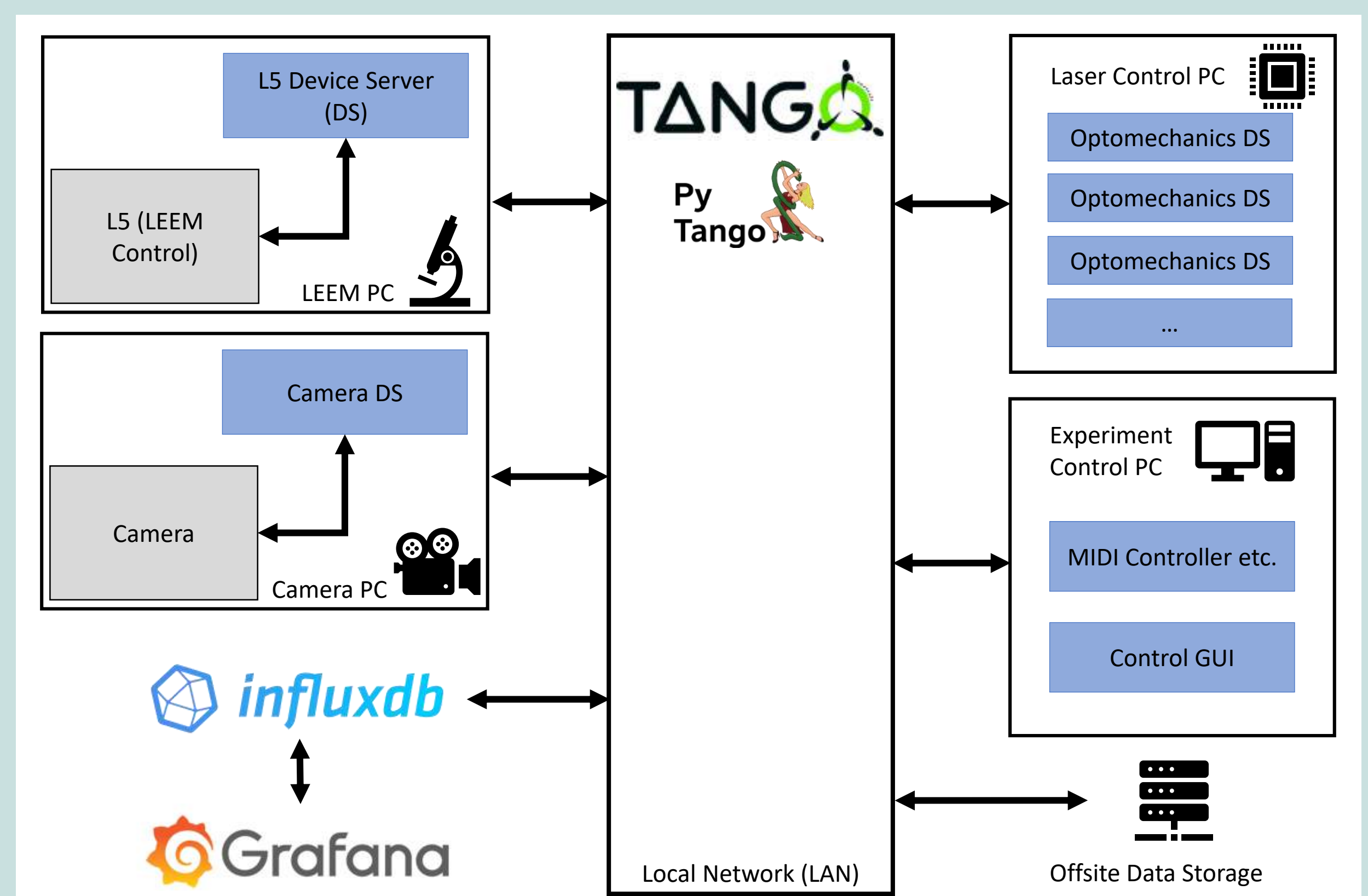
General Properties (base instrument)		Time-Resolved Capabilities	
spatial resolution	5 nm	pump wavelength	1030 nm or 515 nm
energy resolution	spectroscopy: < 250 meV imaging: < 1.7 eV	pump spot size	100-200 μm
sample temperature range	80 to 1500 K	repetition rate	Up to 600 kHz
		optical delay step range	6 fs - 2 ns
		time resolution	est. < 5 ps

**6 Detector:** The Instrument is equipped with a TVIPS GmbH TemCam XF416. The 4096x4096 pixel sensor with 15.6 μm pixel size is capable of recording images with 24fps at 16bit dynamic range. Compared to the standard detector, this allows to use the maximum resolution even with a large field of view.



Darkfield image of Si(100) recorded with the TemCam XF416 with a field of view of 14.2 μm with magnified areas and a line profile to demonstrate the resolution. Images acquired by SPECS during factory testing.

**7 Control Software:** Tango Controls is used as a distributed control system for managing over 30 different devices. Important device parameters are archived into an influxdb. Web access to all archived data is provided by a Grafana web interface.



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