Mechanical Design of the MID Split-and-Delay Line at the European XFEL

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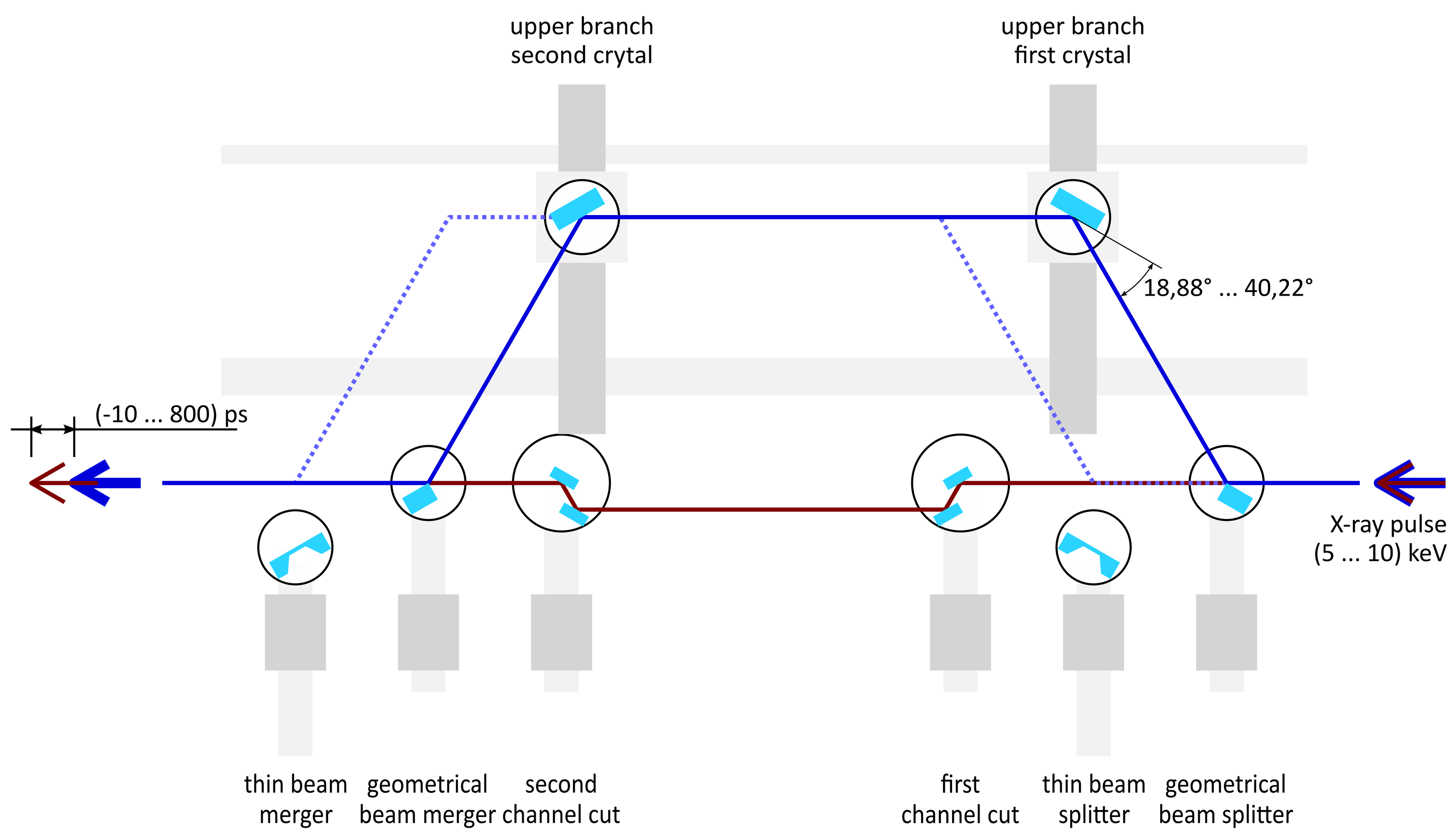
Objective

Mechanical design of a Split-and-Delay (SDL) Line for the Materials Imaging and Dynamics (MID) station at the European XFEL, providing pairs of X-ray pulses for FEL beam energies in the range of (5 ... 10) keV and with a continuously tunable delay time of (-10 ... 800) ps



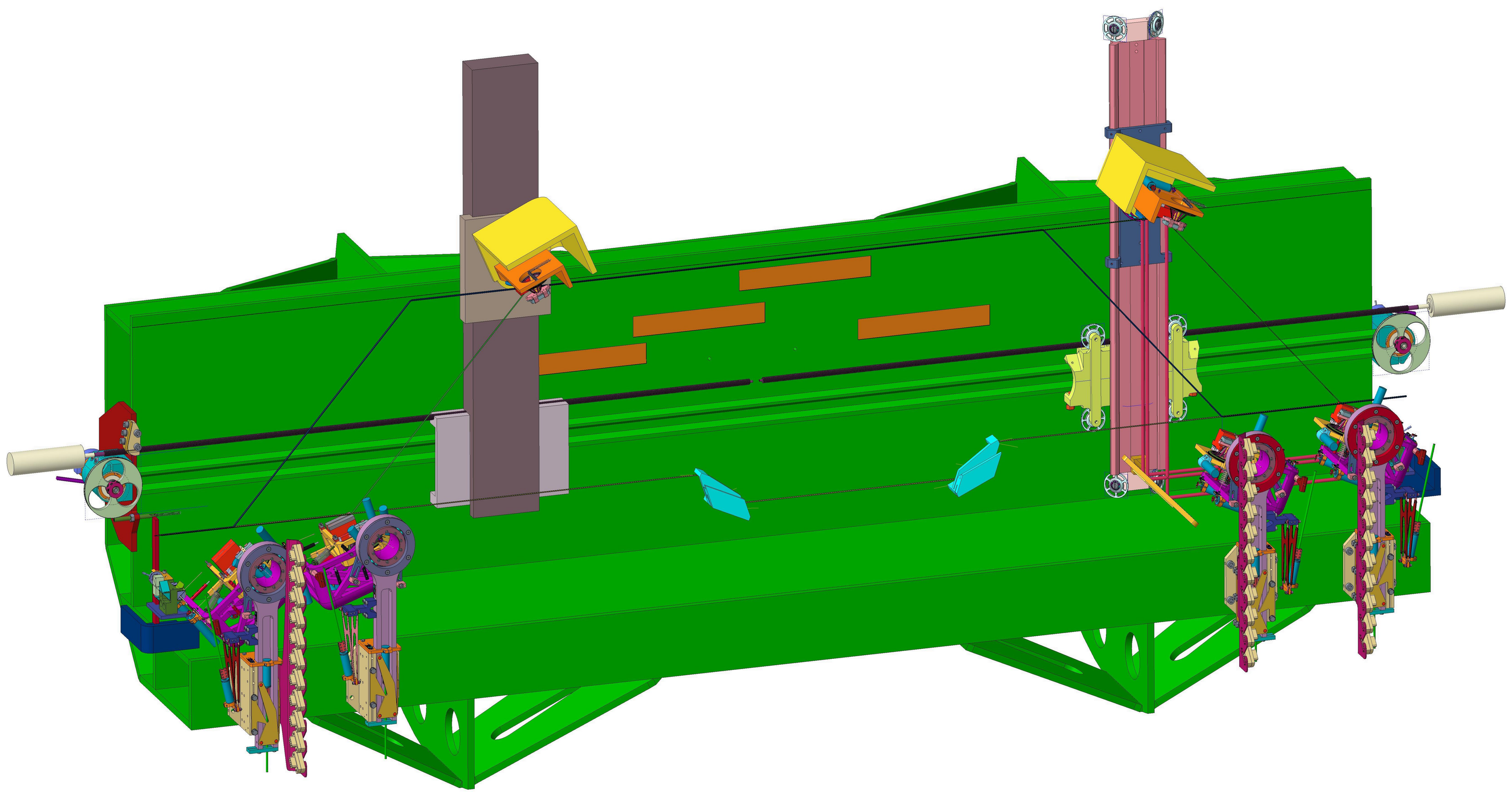
General concept - Showing a conceptual view of the SDL's beam path and indicates the mechanical concept.

Overview

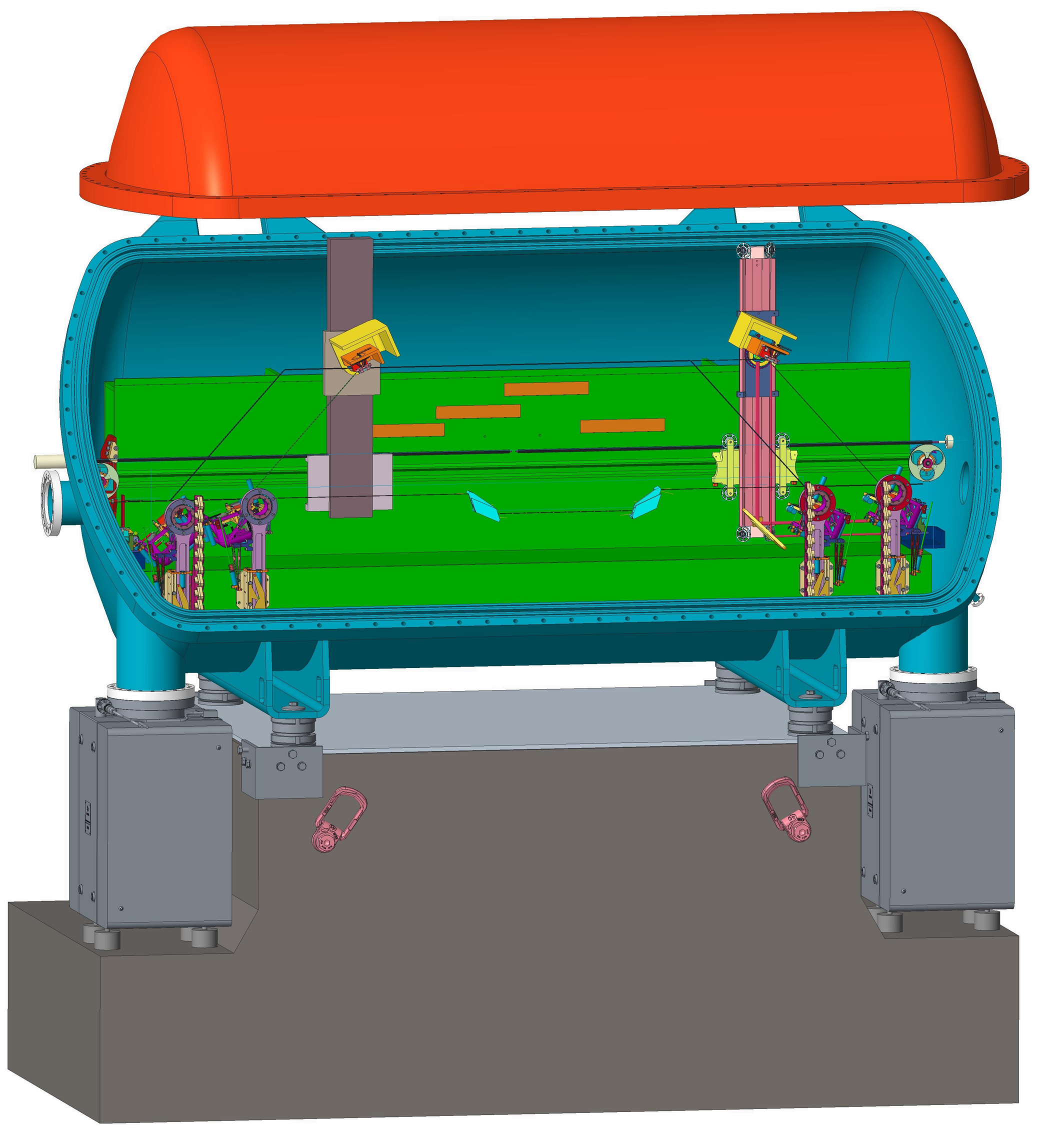
- Installation within the optics hutch of the MID station at the European XFEL
- Provision of X-ray pulses with a continuously tunable delay of (-10 ... 800) ps
- Designed to work with FEL beam energies of (5 ... 10) keV
- Utilisation of Bragg-reflection at silicon(220) crystals
- Setup within an UHV environment
- Motorization of all DoF for quick tuning and adjustment (>100 stepper motors)
- Multiple measurement and monitor systems - including a visible feedback laser system, optical encoders and a multichannel laser interferometer

Mechanical Design

The mechanical concept features separate positioning stages for each optical element. Those stages are based on a serial combination of coarse motion axes and a fine alignment 6 DoF Cartesian parallel kinematics. That allows to meet the contradictory demands of a fast long-range travel of up to 1000 mm and in the same time a precise alignment with a resolution in the nanometre range.
An optical bench acts as stiff supporting structure for those positioning stages. It is installed inside a UHV chamber to minimise disturbing influences to the crucial mechanical components.

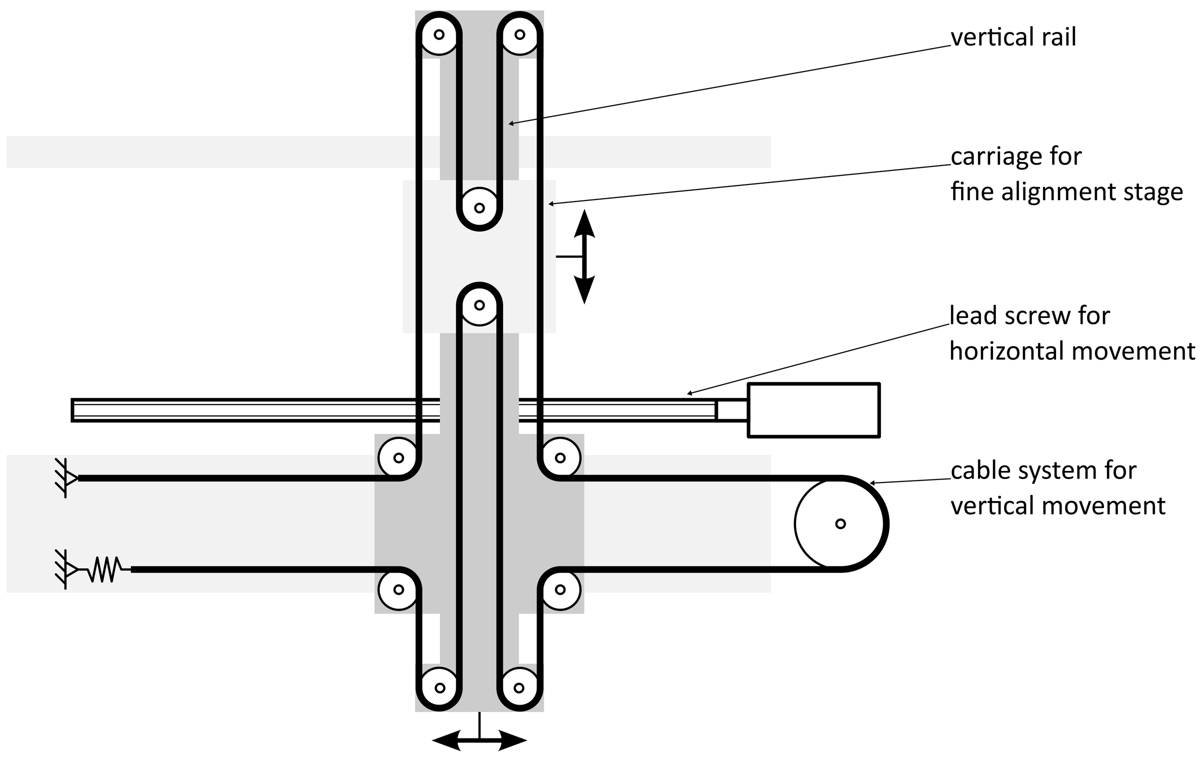


Optical bench - The optical bench suits as support structure, carrying the mechanics for positioning the optical elements and other components such as monitoring and measuring systems. It is designed with maximal stiffness and with as much separation from the chamber as possible- thus providing a most stiff and stable support structure with minimised disturbing influences.



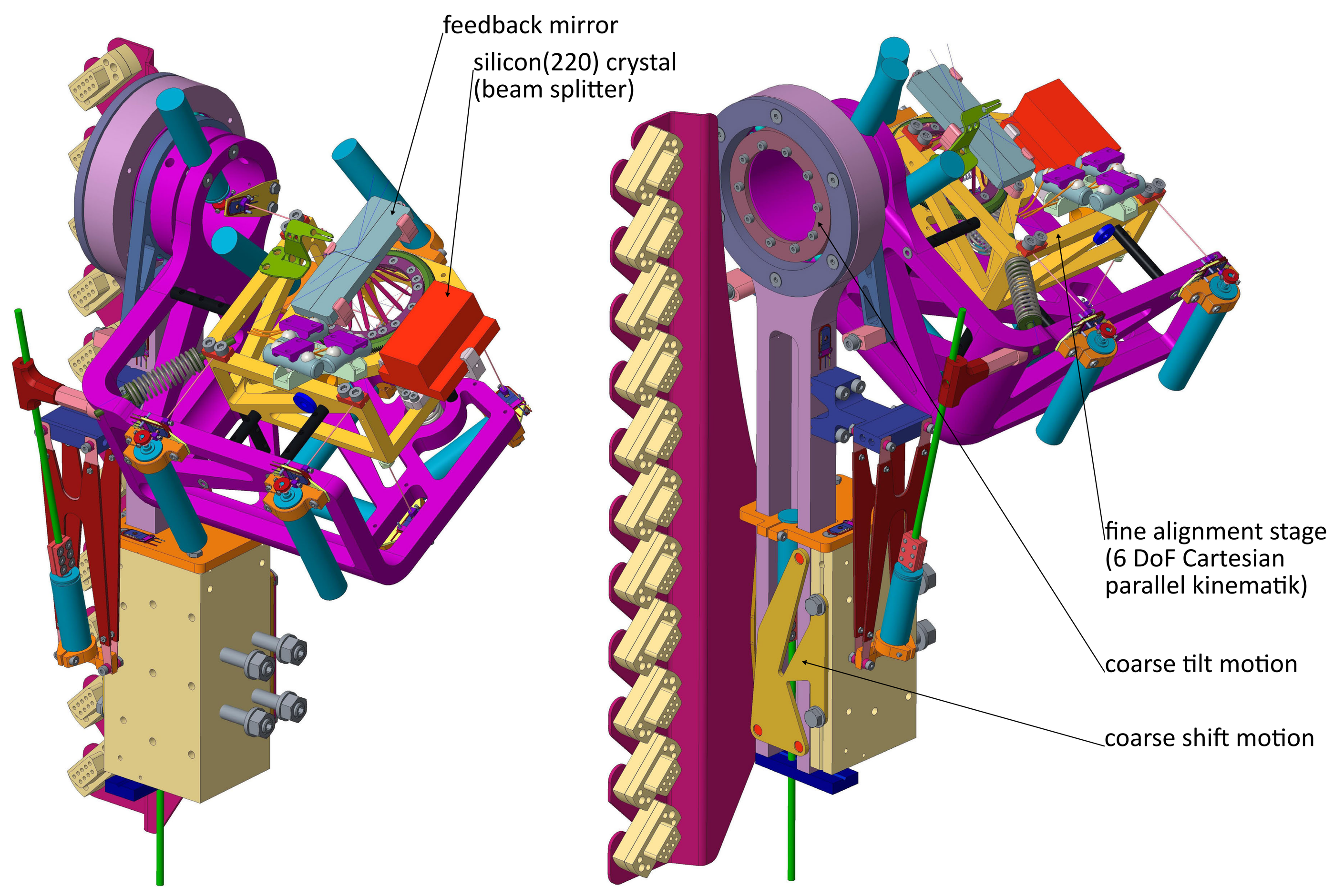
General design of the SDL at its current state - Showing the optical bench with the crucial optomechanics, installed inside a cylindrical vacuum chamber with the dimensions of about (2 x Ø1) m. The chamber stands on a granite block for a most stable grounding. Half of the cylindrical shell can get tilted up, providing a wide and comfortable access to the mechanics.

Driving concept for upper branch translation - The coarse translation of the upper branch crystals is driven by a combination of a conventional lead screw for the horizontal motion and a cable system for the vertical motion. This works analogue to a differential gear and allows to have motors dedicated to both motions individually, while in the same time it allows to have both motors in a fixed position- enabling a better cooling scheme and minimising the thermal impact on crucial mechanical elements.

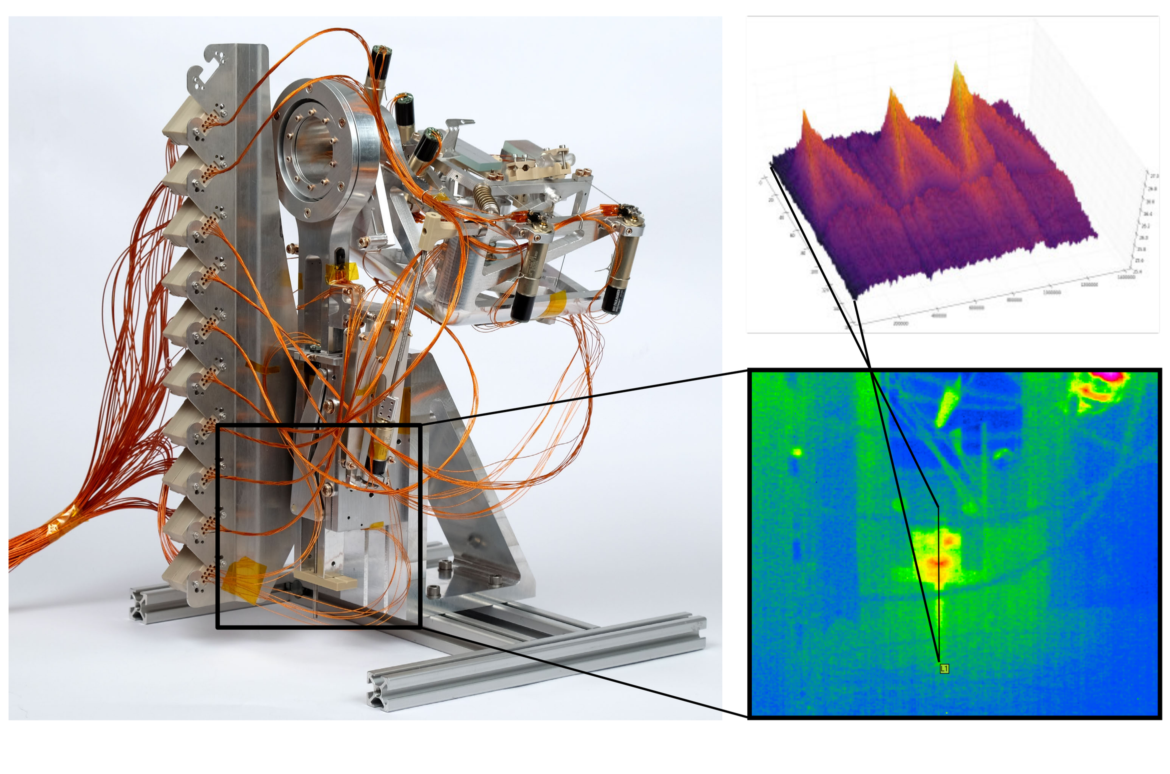


Fine Alignment Stage and Prototype

Fine alignment stage - In order to allow the required nm positioning of the crystals, each one sits on a 6 DoF Cartesian parallel kinematic. Those use spring loaded steel cables, coiled onto a gear shaft to manipulate the position. Both figures show the parallel kinematics for a beam splitting crystal, combined in series with a coarse vertical motion axis (shift) and a coarse rotary motion axis (tilt).



Prototype testing - The Investigation of the prototype showed, that the positioning mechanics as well as the laser interferometer measuring system in general works. In order to obtain quantitative results, the test set-up will be transferred into a vacuum environment. Using a thermal camera, the induction of heat due to the friction between the lead screw and the nut for the vertical shift could be visualised (maximal gradient < 1 K).



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