A high-precision survey and alignment system in inaccessible, high-radiation areas of FAIR: Fundamental ideas

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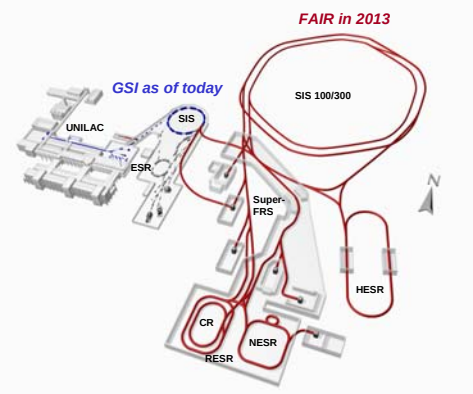
Facility for Antiproton and Ion Research **FAIR**



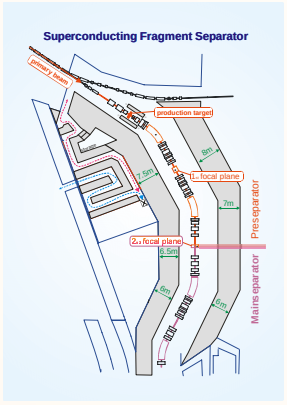
Present and future facilities of GSI

The GSI future project FAIR

GSI (Gesellschaft für Schwerionenforschung in Darmstadt / Germany) operates a large, in many aspects worldwide unique accelerator facility for heavy-ion beams. The research program at GSI covers a broad range of activities extending from nuclear and atomic physics to plasma and materials research to biophysics and cancer therapy.

The intended future facility FAIR (**Facility for Antiproton and Ion Research**) will meet the requirements on higher energies and highest intensities – up to a factor of 10.000. It is based on two superconducting synchrotrons SIS 100/300 with a currently planned circumference of 1190 m and a system of associated storage rings and experimental plants.

After commissioning of FAIR personnel admittance to specific areas (e.g. Superconducting Fragment Separator, Anti Proton Target) for routine maintenance, and consequently for survey and alignment, will not longer be possible due to an expected, very high radiation level. This is said to be true even in periods the accelerator is switched off.



Preliminary scheme of future Super-FRS with non-linear geometry

Therefore a **new survey and alignment system** is necessary, which meets the following requirements:

No access of human personnel

Great demands on **accuracy** (some 1/10 of mm)

Data capture within a **short time**

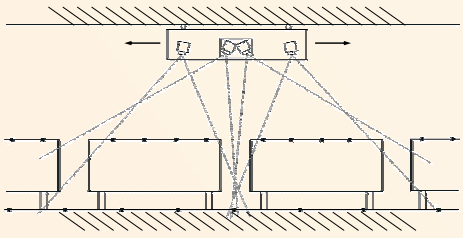
Automatic **remote adjustment** of accelerator components

Handling **non-linear** beamlines with a length up to 50 m

"RALF" - Remote ALignment on the Fly

Basic concept - Photogrammetric solution

A number of high-precision **digital cameras** together with **inclinometers** are installed on an automated guided vehicle system. Via **tracks** this device will be driven along the beamline in the activated area, which has to be surveyed. Appropriate **fiducial points** are mounted on the magnets. In addition **photogrammetric tie-points** and calibrated **scale-bars** are distributed in object space to guarantee a stable photogrammetric network. At least two adjacent components are captured in **one shot**, before the vehicle starts to move to the next stop for taking the following picture. After finishing data acquisition the camera system is lead out to a **radiation-protected storage room** to download the image data and measured tilt angles. A **bundle adjustment** provides **correction values** for the alignment of the accelerator components that is completed by **remotely controlled adjustment devices.** Another camera run is performed to check the quality of remote alignment.



Remote-controlled survey and alignment system on a movable device – basic concept

First research

Camera tests

Two 4-MegaPixel cameras (black and white) have been tested at the facilities of i3mainz. A spatial test field with retro targets and scale bars was captured with up to 30 images under different conditions (inclination and position of cameras).

	SVS4020 B/W CCD Camera by SVS-Vistek GmbH	CSB4000F B/W CMOS Camera by Tokyo Electronic Industry Co. Ltd. (Teli)
Resolution	2048 x 2048	2048 x 2048
Pixel size	7,4 µm	6,0 µm
Image device (diagonal)	21,5 mm	17,4 mm
External dimensions	50 x 50 x 45 mm	54 x 43 x 94,5 mm
Lens mount	M42-, C-Mount	C-Mount
Interface	CameraLink™	FireWire IEEE1394
Prices (approx.)	7.000,- €	4.400,- €

Conclusions:

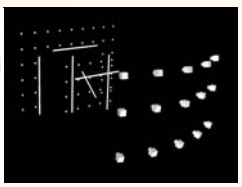
- Relative accuracies of 1 : 40.000 or better should be possible
- Accuracy of image measurement: $^1/_{25}$ - $^1/_{30}$ Pixel
- "Stable" inner orientation at different camera inclinations

Simulations of different net configurations

Net simulations with CAP bundle adjustment software at a similar project resulted in valuable experiences considering

- Net design at stretched objects
- Influence of additional observations on object point accuracy (e.g. camera calibration values, known relative and absolute orientation, scale bars in object space)

SVS4020 industrial 4-Mpixel camera (source: SVS-Vistek GmbH)



Test field and camera positions

Technical challenges and problems

- Influence of gamma (and neutron) radiation on CCD/CMOS chips
- Relative accuracy below 0.1 mm
- Length of beamline up to 50 meters
- Adequate camera configuration versus limited space in tunnels
- Camera vehicle: mode of drive
- Fully remote-controlled camera system and positioning elements
- Radiation tolerance of adjustment devices
- Link to the adjacent machines
- ...

A time frame of three years is planned for conceptual work on a final solution of RALF. After terminating the project the conclusion will help to configure and to build the required infrastructure for the measurement system.

The project started in June, 2004 in co-operation with i3mainz, Institute for Spatial Information and Surveying Technology, Mainz/Germany, and will shortly be implemented into NUSTAR project, funded by the sixth European framework program for research and technological development (EU FP6) .

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