A Photogrammetric Alignment Approach at High-Radiation Areas of FAIR

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Introduced at IWAA 2004, the conceptual design of the alignment system RALF, Remote Alignment on the Fly, has been advanced in the past two years. The goal of RALF is to provide high-precision survey and alignment at inaccessible areas of FAIR, the new international accelerator 'Facility for Antiproton and Ion Research' at GSI, Darmstadt. A photogrammetric approach was chosen for this purpose, facing problems and limitations like high radiation, little space and denial of any human access to the affected areas. This paper will present the status quo of the concept and give an overview of the previous work. This includes the development of a basic concept, evaluation of camera specifications and geometric camera tests. With regard to the expected radiation environment investigations concerning radiation hardness of CCDs were carried out as well as practical camera tests at radioactive conditions. Furthermore simulations of potential camera configurations have been accomplished and possible constraints for the accelerator design have been evaluated. A RALF test installation under realistic conditions is planned for the upcoming months. First parts of FAIR will be commissioned around 2010.Introduction

1. FAIR

At IWAA 2002 the new accelerator facility FAIR, which is planned to be built up next to the existing GSI laboratory (Gesellschaft für Schwerionenforschung) within the next decade, has been introduced [1]. This Facility for Antiproton and Ion Research will boost the intensity of the beam by a factor of 100 to 10,000 and increase the beam energy 20-fold, compared to the present GSI facility. Start of construction is in fall 2007, the completion is planned at the end of 2015.

As presented at IWAA 2004 the conditions at this new facility will make high demands on the survey and alignment of the accelerator components [3]. Personnel admittance to specific areas (e.g. Super-FRS) for routine maintenance, and consequently for survey and alignment, will not longer be possible due to the very high radiation level in some areas of FAIR. Additional constraints are increased demands on alignment accuracy (required fiducial point accuracy: standard deviation 1/10 mm, 1 sigma), the non-linear and stretched geometry of the Super-FRS beam line (up to 50 m) and lack of space due to heavy shielding. Therefore a new survey and alignment system is needed which will provide a fast, automatic and remote-controlled alignment with accuracies up to one tenth of a mm.

The basic concept for such an alignment system will be based on a photogrammetric solution. Close-range photogrammetry is a non-contact geodetic measurement technique that works without human impact on the object and accomplishes flexible measurement and monitoring tasks with highest accuracies.

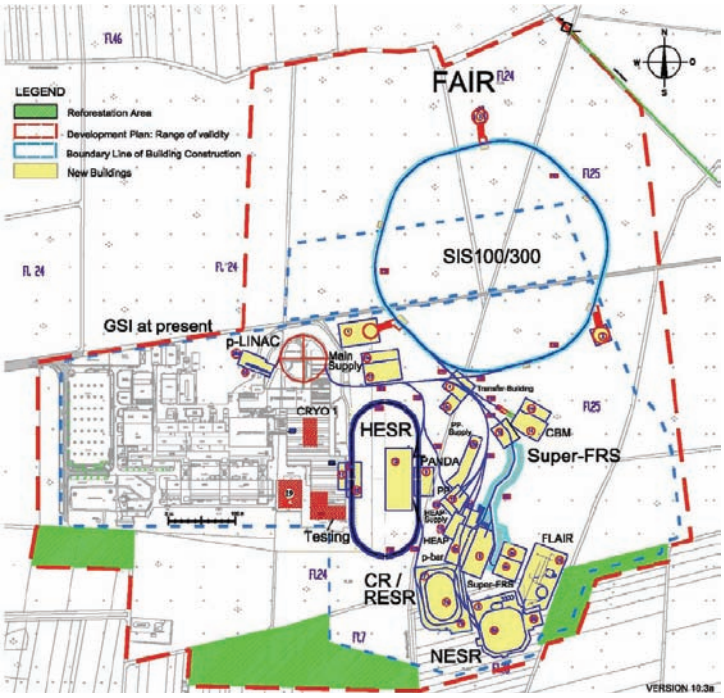

Figure 1: Layout of the FAIR facilities. The new accelerators and buildings (indicated in color on the right in the site map) are located east of the existing GSI facilities (indicated in gray)

1.1. i3mainz

Since the GSI metrology department has no experience with photogrammetric solutions, a cooperation between GSI and i3mainz, Institute for Spatial Information and Surveying Technology of the Fachhochschule Mainz, University of Applied Sciences, was established. The i3mainz carries out Research and Development projects in all areas of geoinformatics and metrology. A total of 18 scientific collaborators and 7 full professors are working on the R&D projects. Summaries and publications of present and past projects can be found at the institute's website [4].

Founded in 1998 the institute has gained extensive theoretical and practical knowledge in industrial photogrammetry over a period of eight years, for instance in the fields of precision metrology, image orientation and image analysis. Several self-developed algorithms are provided as well as a wide range of commercial hardware and software for image analysis, bundle adjustment and camera calibration.

1.2. Basic concept

The project started in summer 2004 was called RALF (Remote ALignment on the Fly) and deals with the conceptual work on an approach for a high-precision survey and alignment system in inaccessible, high-radiation areas. In general the solution is founded (see [3]) on a a remote-controlled vehicle system, which will be driven along the accelerator tunnel. A number of high-precision digital cameras mounted on this vehicle are designated to capture images of the machine geometry, represented by appropriate targets. Provided that the fiducial coordinates of the targets are assigned to the magnet geometry prior to the alignment, a bundle block adjustment of the image measurements of the targets

delivers precise 3d information of the beam line. A comparison to the reference results in correction values for the alignment of the accelerator components that is completed by using remotely controlled positioning elements. Another pass of the control process checks the quality of the remote alignment performed.

In the past two years several investigations have been carried out concerning the design of the vehicle, the choice, number and configuration of cameras and several other aspects. The results will be presented in the following chapters.

2. CONFIGURATION

A rough concept of the proposed surveying and alignment system RALF, as it was planned in 2004, can be seen in figure 3 of our IWAA2004 paper [3]. At this time it could be assumed that there is at least five meters space between the surface of the accelerator components and the tunnel walls. This would have meant enough space to build up a proper photogrammetric network with good angles of the image rays and relatively homogeneous object coordinates. But, however, the environmental conditions have changed significantly in the past two years, according to the conceptual design of the Super-FRS. Figure 2 shows that heavy iron shieldings have been added to the first part of the Super-FRS, preventing any access to the beam line by both personnel and technical equipment. A direct observation of the beam line components is no longer possible, since (a) there is only a few cm to dm space between magnets and shielding and (b) the radiation level during beam time is much too high for any permanently installed measuring or monitoring system. Therefore a new solution has to be found.

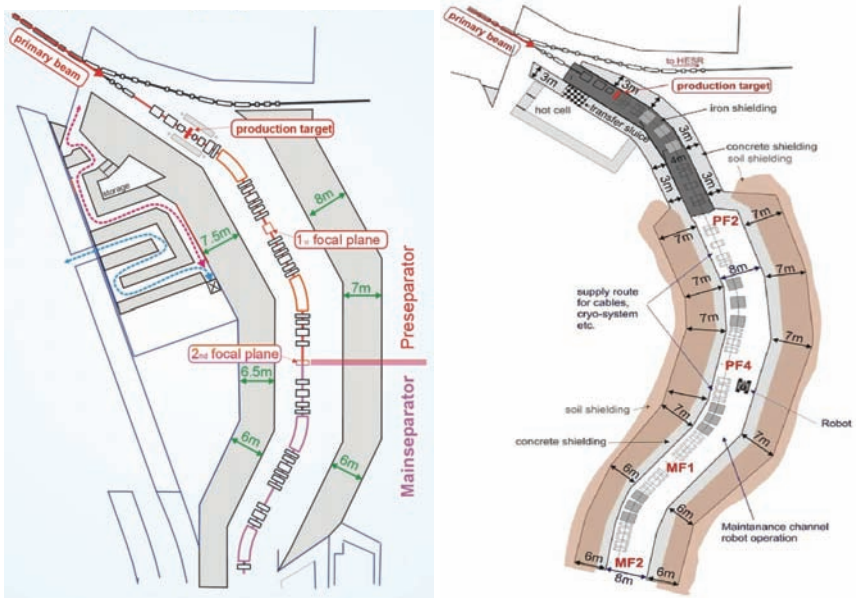

Figure 2: Schematic layout of the Super-FRS with beam line and shielding. Left image: state of 2004. Right image: Actual state. The dark gray printed area from the target to the intermediate focal plane PF2 is now shielded with iron in order to provide a compact radiation protection.

Figure 3 shows a side view of the target area of the Super-FRS. While iron shieldings will be located laterally and below the beam line, a one to two meter thick concrete shielding is planned above the beam line, separating the heavy activated areas from a maintenance working platform. This service platform, where all radiation-sensitive devices are

located (pumps, polymer vacuum seals, media connectors) allows intervention during shut-down periods and therefore it is the only place to carry out any measurement and alignment activities. It is not yet clear if human access will be allowed on the working platform or, in case it is allowed, how long to wait after shut down of the accelerator. Thus the concept of RALF will remain the same: providing a possibility to survey and align the machine geometry automatically, remote-controlled, accurately, reliably and fast.

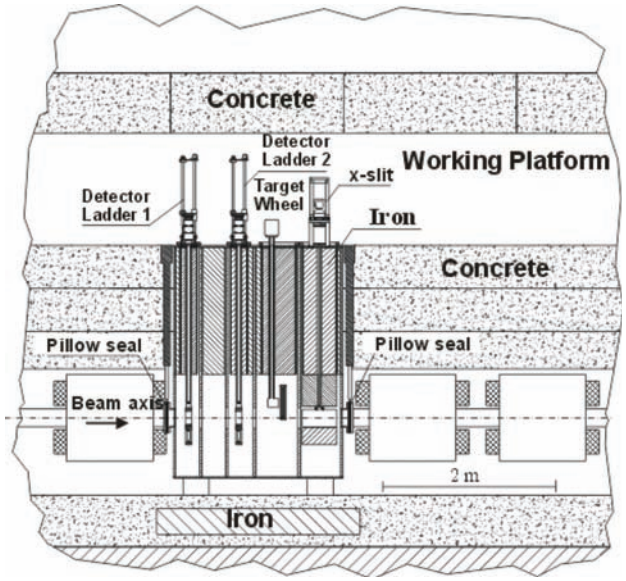

Figure 3: Layout of the target area of the Super-FRS. Any alignment and maintenance work has to be done on the working platform. Therefore the magnet geometry has to be transferred to the platform.

For the existing fragment separator (FRS) at GSI a similar problem had to be solved some years before: due to increased beam intensity and, consequently, an increased radiation level, it became necessary to shield the extended target area with enormous iron plates. The magnets, equipped with fiducial points mounted directly on the yoke, were not visible any more. In order to maintain the ability to check or align the components with the help of the well-established TASA system – based on the use of totalstation and/or laser tracker combined with inclinometers – the fiducials (resp. their supports) had to be extended to outside of shielding. This was done by installing up to two meter long, very stable rods, pulled through holes in the iron blocks and mounted onto the magnet yoke. Sufficient reliability and reproducibility were found by repeated measurements.

It is now intended, to find a similar solution for the concrete shielding between magnets and service platform at the future Super-FRS. It is still under discussion how to solve this in detail. At least three fiducial points per magnet have to be transferred to the platform surface, in order to be able to guarantee an unambiguous alignment in all degrees of freedom. If this is assumed, the design and development of RALF can be continued with only little constraints compared to the fundamental ideas presented at IWAA 2004.

Details on fiducialization of the excentric photogrammetric targets are subject of investigation and have not been fixed so far.

2.1. Simulations of camera setups

In figure 4 the new alignment situation at the Super-FRS is illustrated. The working platform will be approximately 4 m wide and 1.3 m high, referred to the FAIR Baseline Technical Report [2]. In addition to the excentric magnet targets a number of tie-points will be placed around the working platform in order to obtain reliable network geometry. A higher number of image ray intersections will produce more stability and redundancy.

Two camera vehicles, each equipped with two cameras, will then move along the tunnel and take pictures at regular intervals (see figure 5). Thus each photogrammetric target is defined by up to four image rays which should provide enough redundancy to compensate temporary losses of image measurements due to interferences like hidden targets or erroneous target identification and image measurements.

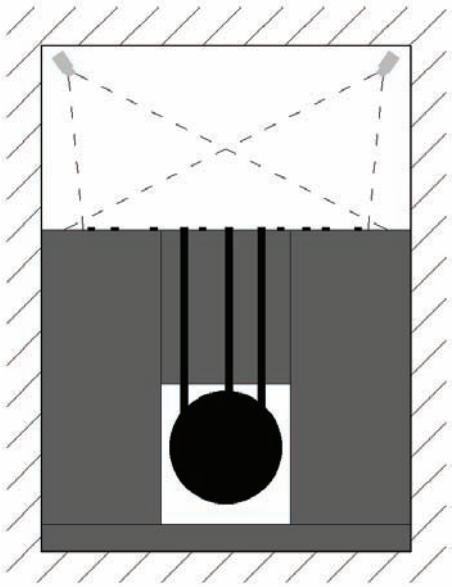

Figure 4: Schematic layout of the heavy shielded areas of the Super-FRS. Shieldings are painted in gray. Three rods are illustrated, which transfer the machine geometry to the working platform. Additional tie points are placed on the ground of the platform.

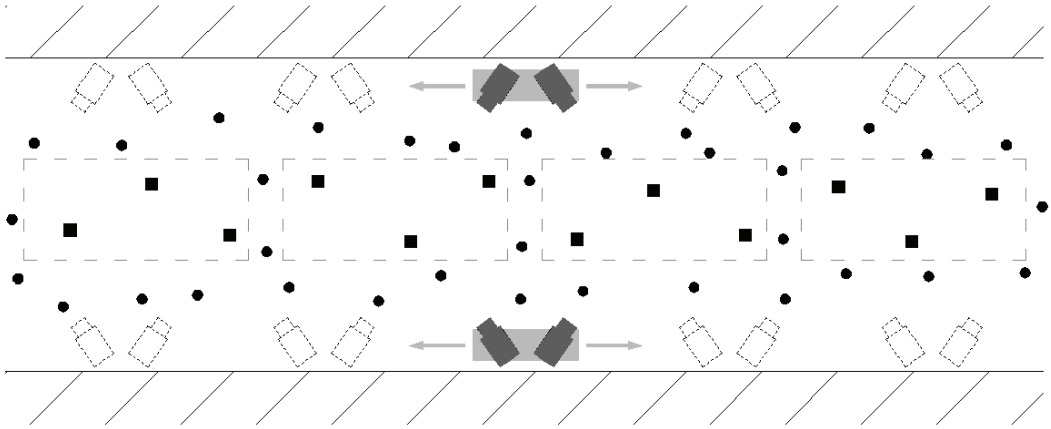

Figure 5: Schematic top view of the working platform. Two camera vehicles, each equipped with two cameras, will move along the tunnel and take pictures at regular intervals. Excentric fiducial points are printed as squares, photogrammetric tie-points are printed as circles.

This configuration was optimized with CAP bundle block adjustment software. In order to obtain information on the achievable object point accuracy it is possible, to simulate the whole configuration without any “real” image measurements. As initial values for the calculation approximate camera parameters, camera orientation and object coordinates are needed. These values can be easily derived from a 3D construction software like AutoCAD or 3ds Max. With the help of the photogrammetric collinearity equations now virtual image measurements can be calculated. In order to simulate “real” measurements, each coordinate is assigned a stochastic error according to the expected image measurement accuracy.

With all this input data a photogrammetric bundle adjustment is calculated. Besides adjusted coordinates and orientations particularly the results of the stochastic model are of interest. The resulting RMS values of the object coordinates are indication for the accuracy to expect with RALF under “real” conditions.

In order to find the optimal solution, the configuration was modified after each iteration loop. As a result of this iterative process, the following configuration was determined:

- cameras: four 4 mega pixel cameras with 18 mm lenses
- image measurement accuracy: 1/25 pixel
- configuration: see figures 4 and 5
- distance between vehicle positions: 2.5 m
- length/width/height of working platform: 30 m / 4 m / 1.3 m
- number of tie points: approx. 300

As shown in table I the resulting object point accuracies in radial and vertical direction are within the requested specifications of 1/10 mm. Only the longitudinal component of the accuracy is worse by a factor 2. But this corresponds to the requirements on tolerances, since position accuracy in transversal respectively vertical beam direction is mostly much tighter than in longitudinal direction.

Table I: Result of simulation

	longitudinal	**Radial**	**vertical**
RMS	0.18 mm	0.09 mm	0.10 mm
Max.	0.32 mm	0.21 mm	0.19 mm

There are several possibilities to improve the resulting accuracies of the object point coordinates. To mention only the most obvious ones: Larger images scales, which are a function of camera resolution, object distance and choice of lenses, will definitely improve accuracy. Moreover a homogeneous camera distribution will lead to a more advantageous network geometry and more homogeneous residuals. But, both actions will either be impossible due to the environmental conditions at the Super-FRS (limited space) or will lead to a considerable increase of cost.

More practical actions for accuracy improvement are the following:

- Introduction of high-precision additional observations (e.g. distances in object space, inclinometer measurements)
- Calibration of camera vehicles (determination of relative orientation between two cameras)
- Intelligent placement of tie-points

2.2. Signaling

The configuration demonstrated in 2.1 needs an appropriate signaling of magnet points and tie-points in order to achieve the desired image measurement accuracies. The “classic” type of targets in close-range photogrammetry is a white or retro-reflective circular target on a black surface. These targets usually are adhesive-backed and can be sticked directly to the object. Black and white paper targets can be easily printed out and are the cheapest way, while retro-reflective targets usually have a 3M™ Scotchlite™ reflective surface and therefore are more expensive.

Retro-reflective targets are widely-used in industrial applications. They have to be illuminated from the direction of image capture in order to produce a nearly binary image (cf. figure 6). With the help of well-dosed illumination and aperture size the images will only show the targets on a black background, without any disturbing object texture. Retro-reflective targets can be identified automatically in a very easy way by defining a simple threshold filter, while the detection of paper targets requires more sophisticated algorithms and is less reliable. Disadvantages of retro targets are costs, susceptibility to dirt or mechanical damage and danger of blooming effects due to overexposure.

Since image analysis algorithms are continuously improved, in the past years black and white targets are increasingly used in industrial metrology instead of retro targets.

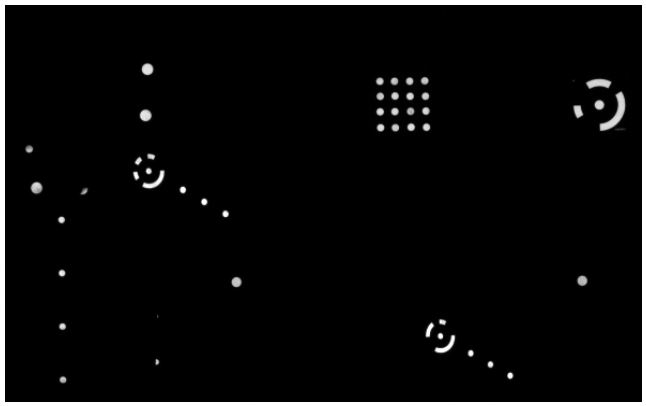

Figure 6: Section of an image of retro-reflective adhesive targets on a wall. Both uncoded circular targets and targets with a code ring for automatic identification are shown. The image was captured with a ring light illumination and small aperture size in order to produce an almost binary image.

But, both b/w and retro targets are only visible in the space pointed by the surface normal [6]. An angle of incidence of less than 30° should be avoided in order to detect and measure the targets in the images reliably and with sufficient accuracy. This constraint leads to problems for RALF. Figure 4 shows that a lot of targets will only be captured under a smaller angle, in case they are stuck horizontally on the platform ground.

A solution would be to arrange half amount of the targets in a way that they are pointed towards the right camera vehicle, while the other half amount is pointed towards the left camera vehicle. This will lead to two separate image bundles, which have to be connected via a small number of additional 3D targets, which will be visible from both sides. Examples of possible 3D targets are displayed in figure 7. The question which types of targets are most applicable for RALF will be subject of further investigation (see 4.).

a) Retro-reflective sphere targets (GMS) b) Cubes with point coding (AICON) c) Color coded cube (i3mainz)

Figure 7: Choice of 3D targets.

3. CAMERA TESTS

3.1. Geometric tests

In preparation for a test installation (see 4.) several cameras have been investigated at the photogrammetric test field, operated by i3mainz [3]. An image bundle was captured with each camera under identical conditions (illumination, image scales, lenses, camera positions). With ImetricS photogrammetric software the targets were identified, the target centers were measured and a bundle adjustment was computed. As a result the RMS values of image coordinates, object coordinates and scale distances provided a basis for comparing the cameras and for estimating the accuracy potential at RALF. The following table gives an overview of the tested cameras and some numerical results.

Table II: Results of geometrical camera tests. Teli and SVS4020 have been tested with a 17 mm lens while a 16 mm lens was used with the other four cameras. All cameras have a 2048 x 2048 chip.

Camera	Mono/Color	Sensor	Image measurement accuracy	RMS of scale distances
Vosskühler VDS CCD-4000C	Color	CCD	1/26 pixel	0.06 mm
SVS-Vistek SVS4021	Color	CCD	1/18 pixel	0.14 mm
SVS-Vistek SVS4020MSCL	Mono	CCD	1/27 pixel	0.06 mm
SVS-Vistek SVS4021	Mono	CCD	1/31 pixel	0.09 mm
Allied Vision Technologies PIKE F421B	Mono	CCD	1/33 pixel	0.09 mm
Teli CSB4000F	Mono	CMOS	1/15 pixel	0.09 mm

In order to achieve the best results in industrial close-range photogrammetry monochrome cameras provide the best image quality and consequently highest accuracies of image measurement. In contrast color cameras lose a certain amount of their native resolution and contrast due to the Bayer color filter. A four megapixel color image, which is converted into a monochrome image, will have a lower resolution than an image, which is captured with a four megapixel monochrome camera. This is reflected in lower image measurement accuracies (see table II).

The Teli monochrome CMOS camera has the lowest image measurement accuracy of all tested cameras. A reason for this might be the characteristic of CMOS (compared to CCD sensors), which has usually a higher noise and more “hot pixels”.

3.2. Radiation tests

Besides the geometrical conditions and limitations at the future accelerator facility for the new survey and alignment system RALF, the radiation environment at some parts of FAIR is the second important constraint, affecting not only human health, but also performance and function of technical equipment. It is widely known that camera sensors are sensitive to high-energetic radiation, no matter if analogue (film) or digital (semi-conductor elements, e.g. CCD) sensors are considered [7]. Hence scientists in astronomy or particle physics use cameras as detectors for electromagnetic radiation (beyond the spectrum of visible light) and particles. When this attribute of camera sensors is desired for the latter applications, it is explicitly unwanted in high-precision metrology. To guarantee high accuracies of the resulting coordinates, it is essential to obtain sub-pixel image measurement accuracies of 1/20 pixel or better. An increased noise or image artifacts, produced by any unwanted radiation will affect the image quality in a way that these accuracies can not be reached.

But the influence of ionizing radiation on digital cameras, used for photogrammetric purposes, has not been subject of detailed investigations in the past [8]. Hardly any scientific publication is dealing with the influence onto the geometric and/or radiometric quality of images used for photogrammetric measurements. Most of the available publications discuss the degradation of CCDs and shortening of lifetime of imaging sensors due to permanent irradiation.

However, much more interesting for photogrammetric purposes is the quality of the recorded images in terms of contrast, noise, resolution, radiometry and geometric stability. Furthermore, it should be distinguished between the damage to individual images, which only occurs during radiation, and image effects resulting from permanent damage of image sensors after heavy radiation. Thus a damaged camera might still be useable as a monitoring camera (e.g. in a nuclear power plant), when it’s already useless for photogrammetric measurements due to large noise or other effects.

The main question regarding the use of photogrammetry in a radioactive environment is: Will the cameras be damaged and will the images be useable for precise sub-pixel measurements? The equipment in the accelerator tunnel primarily is exposed to gamma and neutron radiation. Neutrons only occur during beam time while gamma radiation is a result of matter activation by neutrons and thus is permanently present during shutdown times (when the alignment is done). According to a preliminary estimate the expected level of gamma radiation during maintenance periods will be at dose rates of about 10 mSv per hour, which amounts to half of the allowed dose per year for radiation exposed personnel [9]. This value only is expected in the accelerator tunnel behind PF2. On the working platform between target area and PF2 the expected dose rates will be much lower.

To investigate the influence of gamma radiation on the image quality of CCD cameras, a test scenario was set up. For this purpose we were provided with two industrial CCD color cameras AVT Marlin F-145C2. Marlin cameras are often used in photogrammetric applications and represent a typical imaging device possibly being used for the later alignment task, although higher resolution will be likely (see previous chapters).

Two different test procedures were planned during irradiation:

- “Dark” exposure with closed lens cap for detection of dark current noise and hot pixels,

- “Illuminated” exposure of different targets for determination of resolution, contrast, accuracy of image measurements and noise.

As test installation the TRIGA research reactor could be used, which is a research facility at the Johannes Gutenberg University of Mainz. One main use of the TRIGA reactor in Mainz is neutron production for the purpose of irradiation of different samples and materials. Therefore the reactor offers several possibilities to place the sample close to the reactor core. One side-effect of the neutron production during reactor operation is the activation of the core with its surroundings, which guarantees a radioactive environment with the required gamma dose rates even when the reactor is shut down again. Depending on the power and duration of reactor operation, different levels of gamma dose-rates will be achieved.

3.2.1. “Dark” exposure

The test procedure was as follows: First, the camera with closed lens cap was connected to a notebook via a 10 m long FireWire cable. Before irradiation and after a warm-up period of the camera reference images were taken in order to determine the as-is state of the sensor and to measure mean value, standard deviation and maximum gray value of the images.

Then the reactor was started for a few minutes, depending on the desired gamma level. After shut down, the camera was put into a small polyethylene container and lowered down to the reactor core (see figure 8). Depending on the position of the container, different dose rates could be achieved. The dose rate was measured with a radiation sensor which was also arranged in the PE container. With this setup dose rates of up to 100 mSv/h could be tested.

Figure 8: Left: Polyethylene container which carries camera and radiation sensor. Right: Top view of the reactor core with PE container. A 6 m water column protects people against radiation.

In total 59 images were taken in two sessions at the dark exposure setup. The results showed that the absolute change of the mean gray value was not significant (it was 0.00 in all images). But instead the standard deviation, the maximum gray value and the number of gray values larger than 0 changed significantly during the tests. There is an apparent correlation between dose rate and these values (see Table III).

Table III: Results of setup 1 “Dark exposure”.

Dose rate (mSv/h)	Mean gray value	Std. dev.	Max. gray value	No. of gray values >0
0	0.00	0.06	18	898
5	0.00	0.09	34	1602
10	0.00	0.10	48	1172
20	0.00	0.10	41	1393
60	0.00	0.14	50	2011
100	0.00	0.15	47	2836

The histograms of the images confirm that there is a slight increase of noise in the images as well as an increase of the number of hot pixels (cf. Figure 9, right image). For a better presentation the image histograms have been stretched, hence pixels, appearing to be white, have in reality gray values lower than 40.

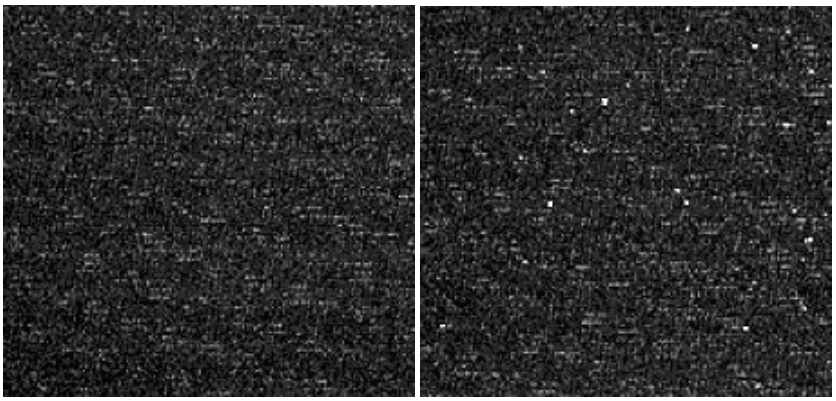

Figure 9: Section from images without radiation (left) and with 100 mSv/h gamma radiation (right). Histograms are stretched to make “hot pixels” visible.

At dose rates of only 10 mSv/h, which amounts to one tenth of the dose rate of the right image of Figure 9 and equals to the expected dose rates at FAIR, almost no hot pixels could be detected. Thus the penetration of the gamma radiation through the camera housing and the resulting impact onto the chip itself is low and should not have serious consequences for the photogrammetric measurements as to be expected at GSI. The tests even showed that the influence of a cold camera in contrast to a warmed up camera on the amount of noise and number of hot pixels is at least as significant as the influence of gamma radiation below 100 mSv/h. Furthermore no permanent damage of the image sensor could be detected. The accumulated dose after these tests was approx. 28 mSv.

3.2.2. “Illuminated” exposure

For the second test series a different setup had to be chosen since it was not possible to take images within the PE container. For this purpose a “thermal column” was used: this is a 1261 mm long and 100 mm x 100 mm wide slot which penetrates the concrete shielding and which ends close to the reactor core. With the help of a Plexiglas

construction, the camera, an LED ring light, a target and a radiation sensor were mounted on a carrier (Figure 10). Depending on the position within the thermal column different dose rates were realized. However, in contrast to the measurements in the PE container, only dose rates up to 8 mSv/h were possible due to safety reasons.

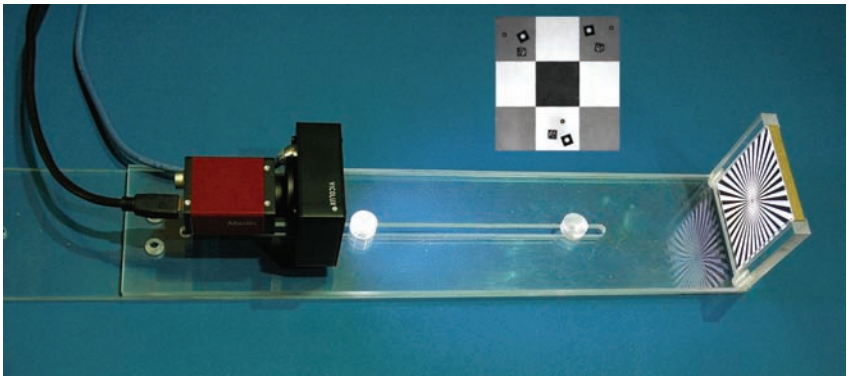

Figure 10: Plexiglas mount with camera, ring lighting and Siemens star target. The small image in the middle shows the second pattern with different colored areas and photogrammetric targets.

Two different targets were used. A Siemens star served as a device to test the resolution or possible changes of resolution during irradiation, respectively. A second plate contains both photogrammetric targets to test the image measurement accuracy and different colored surfaces (white, grey, black) to investigate noise and hot pixels.

As to be expected from the dark test results, both the image resolution and the accuracy of the point measurements remained unchanged during irradiation. The image measurements were accomplished with a template matching algorithm. The accuracy (RMS value) of the matching process was between 0.013 and 0.017 pixel for large targets (25 pixel diameter) and between 0.021 and 0.025 pixel for the smaller targets (7 pixel diameter). The resolution tests with the Siemens star showed a circle of confusion of 28 to 30 pixel in all images, independent of the dose rate.

3.2.3. Conclusion

Fortunately the practical tests showed that no significant interference of radiation concerning measurement accuracy and camera life-time will occur. Nonetheless the research showed clearly that there *is* a definite influence on some image parameters, like noise, dark current and number of hot pixels. The more radiation the camera has to face, the more erroneous and noisy the images will be. Starting from dose rates of 100 mSv/h the radiation effects will probably have to be considered when high precision measurements have to be carried out. But since the so far predicted dose rates at FAIR (esp. Super-FRS) are less than a tenth of 100 mSv/h, a successful employment of the photogrammetric method in this respect can be expected.

4. FUTURE WORK

4.1. Test installation

After all these “theoretical” investigations and simulations it is intended to build up a “real” test installation in the upcoming months. The idea is to establish a situation very close to the one, which will be met at certain areas at FAIR: stretched geometry and little space. The scale of the planned setup should be close to 1:1 compared to the geometry at the working platform of the future Super-FRS. The construction is planned to be build up in a way that single “components” can be moved manually in order to check if RALF is able to detect the movement and restore the original position. Traditional metrology (tacheometry, laser tracker) will be used to verify the photogrammetric measurements.

For reasons of costs at first only two cameras were purchased instead of four. The decision was made to acquire two F421B monochrome cameras by Allied Vision Technologies. Reasons for that decision are the excellent geometric test results (see table II), the good support during the camera tests, a large selection of available equipment and the moderate price compared to the other cameras.

Figure 11: Allied Vision Technologies Pike 421B camera used for the test installation

Table IV: Camera specifications

Image device	1.2“ type progressive scan KODAK CCD
Image format	2048 x 2048
Pixel size	7.4 µm x 7.4 µm
Resolution depth	14 bit
Lens mount	C-Mount
Digital Interface	IEEE 1394b; Fiber
Dimensions	44 mm x 44 mm x 90 mm (w/o lens)

The two cameras will be fixed on a stable carrier which is mounted on a usual camera tripod or a column stand. Since only two cameras were purchased, the “camera vehicle” will have to move around both sides of the test platform in order to simulate the configuration shown in figures 4 and 5. The target or object area might consist of movable components, for example euro-pallets. These components have to be equipped with targets. It is intended to test different types of flat and 3D targets in order to find the best solution (see 2.2). Depending on the used targets also different types of illumination will be tested.

The captured images will first be stored on a notebook. The image analysis and bundle adjustment will be carried out with commercial software and/or self-developed algorithms. Possibly also different types of data transfer can be tested, since the acquired cameras support both Firewire and Fiber interfaces. With the latter, very long cable lengths are possible, which will probably be necessary for the RALF system.

With the help of the test installation we hope to confirm the positive results of the previous, mostly theoretical, investigation to be able to define a fixed concept for RALF in summer 2007, which will be the end of the research project.

4.2. Practical aspects

Besides the photogrammetry part of RALF some practical aspects have to be considered in order to define a concept for the measurement and alignment system. Most of these tasks are still to investigate and will be treated in the future:

- Definition of constraints for the civil construction of the accelerator buildings
- Storage and protection room for camera vehicle
- Remote-controlled adjustment of accelerator components
- Design, mounting and actuation of camera vehicle
- Data transfer camera vehicle – control computer – adjustment devices
- Fiducialization of excentric targets
- Illumination

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