INTERIM SCIENTIFIC REPORT

Second Execution Phase of ELICAMM-GAMMA Project

TITLE:
Implementation of functional models for Interaction chamber with integrated alignment system into the high energy gamma beam

Report content

1. Annual Summary Document (for financing from Budget of 16ELI/2016 project Annual report) (see Annex 1.A)
2. Interim indicators of project implementation (see Annex 1.B)

SCIENTIFIC REPORT

ANEXA 1.A

Annual Summary
September 2016 – November 2017

Summary of accomplishments during the reporting period.

The team pursuing the project's implementation plan carried out the following activities:

- Analysis and studies of several constructive solutions for alignment of the interaction camera with integrated actuators on high energy gamma beam.
- Analysis of constructive solutions of interaction chamber.
- Selection of appropriate raw materials susceptible to be used for scintillator lens in accordance with the gamma beam specific.
- Selection of high resolution, precision and sensitivity sCMOS digital camera necessary for alignment system of interaction chamber into the high energy gamma beam.
- Opportunities analysis of using a supplementary alignment collimator SWOT Analysis used as static reference of the alignment system.
- Design of all system components: mechanic, optic, and electronic elements (see details into the scientific report).
- System design.
- Specification of the interaction chamber firmware (workflows, image acquisition, human machine interface, digital communication functions).
- Implementation of interaction chamber, acquisition of X-Y precision actuators able to functioning into vacuum environment; chosen of actuators placed outside interaction chamber; acquisition of sCMOS digital camera; design of optical system necessary for collimation of scintillator image to sCMOS digital camera
- Acquisition of main ELICAMM-GAMMA components: actuators for X-Y movement of probe holder
- Design of the test use-cases, of testing, calibration and validation procedures for system' components and whole system.
- Implementation of an experimental model including the principal actuator of sample holder inside the interaction chamber, the ultra-sensitive and error free digital camera, and all the afferent components necessary to assure the implementation of the alignment system principles
- Testing and calibration of the alignment system in laboratory
- Organization of a workshop into the frame of COMEC 2017 (International Conference on Computational Mechanics and Virtual Engineering 2017), organized by Transilvania University of Brasov, Romanian Academy of Technical Sciences, and Romanian Society of Mechanical Engineering in period November, 16-17, 2017. With this event, the team was presented two papers related 16ELI/2016 project and also made the outreach of the project in front a special session organized related above-mentioned event.

2. Scientific accomplishments (max. 3 pages) – Results obtained during the reporting period.

Annual summary report (Results obtained during the reporting period 1/09/2016 12/12/2016)

The annual report refers from September 2016 till August 2017 period in which the working groups of ELICAMM-GAMMA project, lays on analysis and generation of the state of the art relative to an alignment system for the interaction chamber (IC) for nuclear resonance fluorescence (NRF) in report with the γ beam emitted by the ELI-NP high power laser system. Several potential solutions were analyzed in this stage with their advantages and disadvantages. The alignment system constrains, its structure, mechanics of the action mechanism sand components were reviewed and a detailed study for each component was done. Two issues remain open and may constitute sources of future trouble. First, *the real possibility to find, identify and have an optical representation of γ beam* emitted and the second, to *identify and remove the potential error in the action system*. To reach these two targets a special attention was paid for the analysis of the potential sources of errors in detection of γ beam (sensors, conversion of γ beam in a beam in visible spectrum, data or/and camera acquisition system, control of alignment system and acting system that must assure the precise positioning of IC in γ beam direction). Also, the methodology and afferent algorithms for alignment system were analyzed.

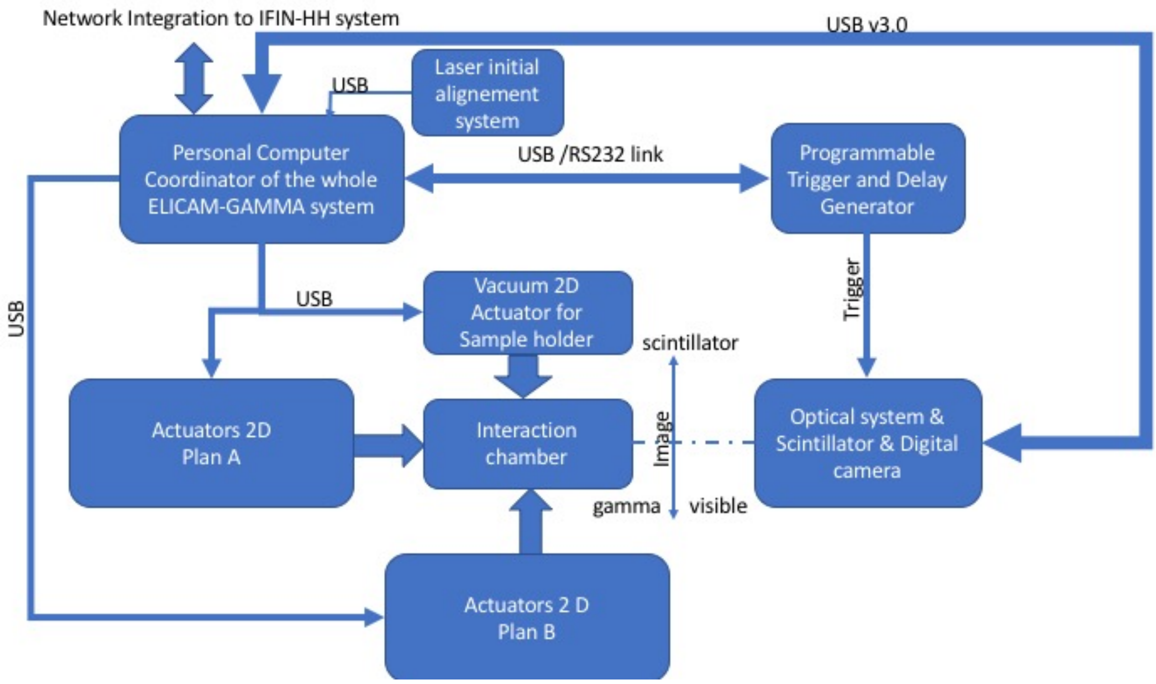

Figure 1 Block diagram of ELICAM-GAMMA system

Going forward with the analysis, the ELICAM GAMMA team has investigated the possibilities to use appropriate solutions for conversion of gamma "image" into a visible image using adequate scintillators. The BGO scintillators are considered as adequate for this application. Special attentions were paid for simulation of interaction between gamma beam and scintillator material (see first report). Also, market analyses were done in order to find out the potential appropriate digital camera susceptible to be use for image acquisition and for the afferent optical system. In this sense we have considered a sCMOS camera with excellent features related SNR, sensitivity, resolution and triggering features. For the manipulation of the sample holder a precision acting system that functioning in vacuum were chosen. The alignment system (see Figure 1) use a γ beam detection system that provide information to a computer using a data acquisition or an image capture system. In front of digital camera, a γ beam to visible beam converter (scintillator lens) must be inserted. Using Ge based detectors or an optical system including scintillator, mirror and sCMOS camera, an image of the γ beam must be acquired by the alignment control system (in our case a computer that is linked to the γ beam detectors). The used digital camera will be placed out of γ beam direction in order to avoid interaction between γ photons and camera sensitive pixels. The computer is endowed with programs that implement an algorithm able to quick scan and detect the most intense area collided by the γ beam. The programs are able to recognize contours, and patterns with similar "color". Also, these programs convert the pixel view in absolute distance using a calibration image.

The interaction chamber is clamped on two plans where 2 actuators assure the movement of the interaction chamber on gamma beam direction. The kinematics of acting system was designed and simulated. In order to have an initial "reference position" a laser visible beam independent alignment system will be use. This will assure the raw alignment of interaction chamber and the designed system will take this point as a reference for all future alignment commands done on actuators. As measurement principle, an image of elements that can attenuate or generate traces of gamma beam will be identified by capturing the initial image on digital camera. The image of sample holder and the other interaction chamber elements we suppose that will generate a characteristic shadow on scintillator and implicitly this will be captured through optical system by the sCMOS digital camera. These patterns will be display on computer monitor and the operator will can interactively indicate the object use as reference. After a first step, when a potential mark will be identified the system will automatically calculate the alignment error and will adequately command the motors in order to minimize it.

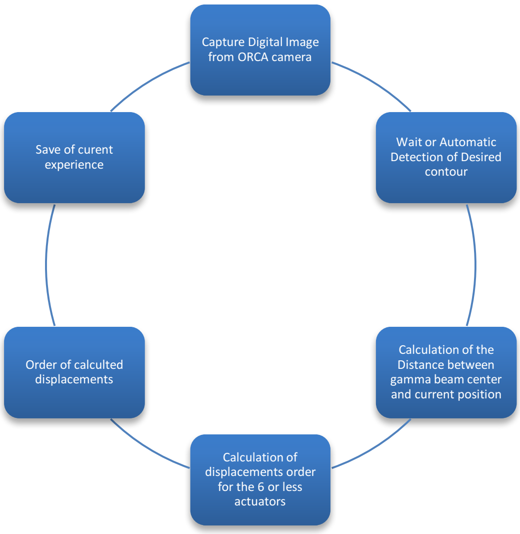

Figure 2 Main workflow diagram of ELICAMM-GAMMA system

The capturing of image by digital camera will be synchronized as acquisition with the main signal provided by ELI system in order to avoid the errors related sampling period in image acquisition.

The software developed will implement a workflow in accordance with developed methodology is illustrated in Figure 2.

The system design and also the functions necessary to assure the implementation of alignment system were developed.

This algorithm will command periodically the acquisition of images from digital camera, and the successive images will be comparing in order to detect the eventually relative sliding of beam. The system will be considered aligned when the signal acquired by the image analysis system will reach an extremely value. The IC-NRF will be act be 6 linear actuators that will provide the alignment in two plans: orthogonal on γ beam direction and centered with the γ beam. The movement of the actuators will be inter-correlated by the computer.

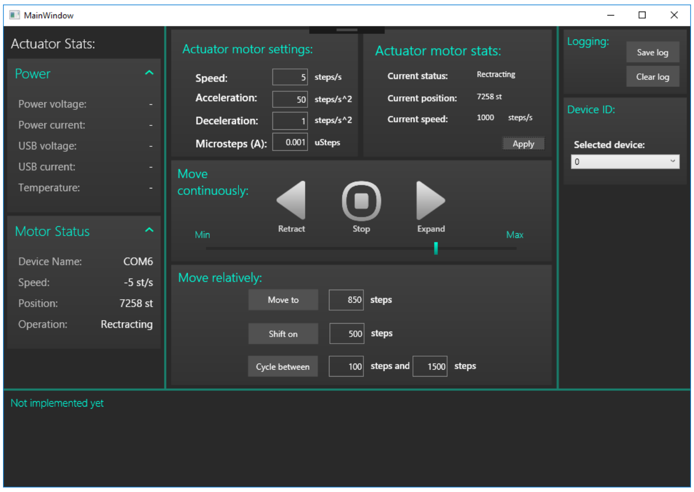

Figure 3 Acting system interface for manual positioning of the sample holder inside the interaction chamber

The project' team implemented the main elements of the alignment system: interaction chamber, acting system for the sample supposed on tests, the image acquisition system necessary to provide the position feedback of sample holder and the firmware necessary to implement designed functionalities.

The design of the interaction chamber was modified in order to adapt it at the dimensions and functional needs demanded by insertion of the two (X & Y) actuator supporting the sample holder. Also, the necessary adaptation for the external positioning system, based on 4 actuators acting in two planes was designed. The four actuators were selected and are in train to be procured.

For the acting system, a first version of the firmware necessary to control and to be integrated with the data acquired by the digital camera was implemented and tested. The human machine interface is illustrated in Figure 3.

For the digital camera, the team involved in software development was designed and tested the routines necessary for "live" and "snapshot" image acquisition necessary for implementation of alignment algorithm. Also, the increasing of image' contrast and focusing of region of interest was implemented.

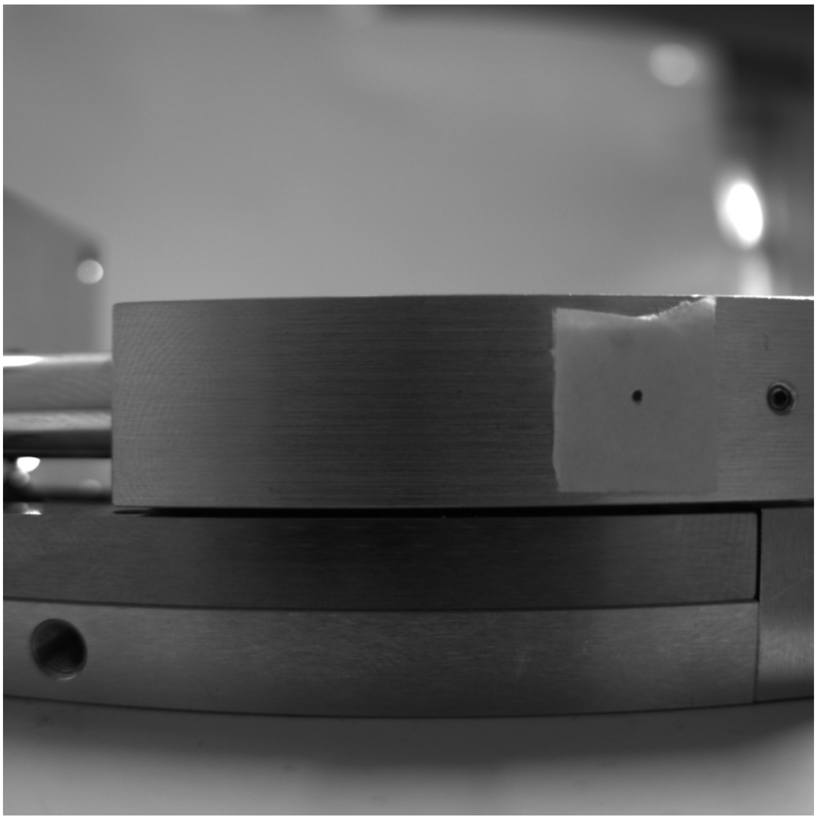

Figure 4 Sliding sleeve of the actuator with a reference point used for testing the repetitive movement that illustrate the accuracy in positioning of sample holder based on firmware developed. (represent achievement of a component test for alignment system)

The alignment algorithm was developed in a first version (see Figure 4) , using software components developed during this stage. Thus, were verified the “real-time” constraints operation for the whole system, the accuracy of the positioning system testing different algorithms and speed profiles in control of the X&Y actuators. The system was tested in conditions of closing the automation loop, respectively controlled automatically using the image acquired and processed by high sensitivity and accuracy digital camera.

A routing for serial acting and testing positioning accuracy was conceived and tested, giving technical satisfaction and complying at all initial requirements.

In period 22-24 of November in the frame of COMEC 2017 (International Conference on Computational Mechanics and Virtual Engineering 2017) a special session was organized in order to spread the project achievements in the community of mechanical engineers. With this occasion two paper were presented illustrating the main original contribution obtained by the 16ELI project team during project implementation.

4. Deliverables in the last year related to the project:

- List of papers (journal or conference proceeding):

1. Calin ITU, Sorin Vlase*, Consuello Sofia PENA, Paul Nicolae BORZA, Mircea Mihalcica, UNIVERSAL ABSORBER APPLIED to NVH in EV’s POWERTRAIN, International Conference, AVMS2017, mai, 2017, Timisoara
2. Sorin Vlase*, Paul Nicolae BORZA, Gabriel SULIMAN, Cristian PETCU, Maria Luminita SCUTARU, Marius GHITESCU, Nastac Cristian, DYNAMIC ANLYSIS OF THE INTERACTION CHAMBER FOR THE ELIADE ARRAY, International Conference, AVMS2017, mai, 2017, Timisoara

3. Sorin VLASE, Paul Nicolae BORZA, Maria Luminita SCUTARU, Mircea MIHALCICA, Gabriel SULIMAN,, Cristian PETCU,, Marius GHITESCU , Arina Modrea, Optical analysis of the reaction chamber for the ELIADE array. 11th International Conference Interdisciplinarity in Engineering, INTER-ENG 2017, 5-6 October 2017, Tirgu-Mures , Romania
4. P. Borza, M. Baritz, S. Vlase, G. Suliman, C. Petcu, Study of the optical system for the alignement of the interaction chamber for gamma beam, Proceedings of COMEC 2017, Brasov Romania
5. S. Vlase, P. Borza, S. Vlase, G. Suliman, C. Petcu, Study of the mechanical system for the alignement of the interaction chamber for gamma beam, Proceedings of COMEC 2017, Brasov Romania

5. Further group activities (max. 1 page):
An outreach activity was provided with the occasion of COMEC 2017, Brasov Romania, Conference.
6. Financial Report (budget usage) for the reporting period (see the Annex).

7. Research plan and goals for the next year (max. 1 page).

Experimental validation must continue with all the alignment components and is necessary to in the future period to achieve the mechanical and vacuum tests for interaction chamber in order to validate whole hardware components. Related the optical system, in the near future (end of 2017) the team will arrive at a feasible solution for projecting the image scintillator on sCMOS digital camera sensor. of the functional models of interaction chamber with integrated system for alignment. An important problem that will need to be solved in the very close future is related to the implementation of the adequate scintillator components. For the moment, this problem required some feasible solutions and the team making significant efforts to find out and to assure the procurement of such scintillator. In the next stage will make experimental research of interaction chamber with integrated alignment system (2 versions). As result of the first experiments with a simplified optical system, the team consider that the final configuration of optics can be simplified respectively, the first lens placed on gamma beam axis can be eliminated and only the focusing lens will be used for projection of image obtained on scintillator will be mounted. Also, in this way, the attenuation of the image will be reduced (see Figure 5). After completing the constructive variant will be performed experiments using a Gamma beam. It is estimated that in 2018 will be available a Gamma beam source of low energy that can be used to test the interaction chamber (2 variants). It is also considering testing to other laboratories worldwide that can be offer a Gamma radiations source. In the end, it does experimental validation of the proposed system, designed and accomplished.

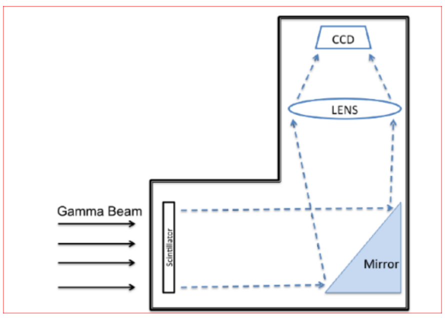

Figure 5 Principle of the alignment with CCD

Finalization of experiments; Project achievement and reporting, tests, calibration and validation of the implemented system. Based on the results achieved in the previous phases of the project, an experimental model will be defined. As result of experiment settlement, the design of components and their integration into the system will be launched in execution. The ideal scintillator screen should have a high density, a short decay time, high light yields and be radiation resistant.

At the end of this phase two different models will be ready for experimental tests