Simulation and design of the ELI-NP positron source and the slow positron beam pulsing system

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Abstract

The thesis presented the general plans for the ELI-NP positron spectroscopy laboratory together with a detailed account of two particularities.

For the thesis a Positron Annihilation Spectroscopy experiment was carried out, for the characterization of one type of field assisted moderator material, GaN thin films, by DBS, while the latter method, together with PALS were employed in order to determine the optimum annealing parameters for the ELI-NP material of choice for the γ to e^+ conversion and fast e^+ moderation. In the present study out of all four samples the best effective positron diffusion length was obtained for the 500 nm thick GaN film grown on a SiC substrate, to be 75 ± 20 nm. The studied materials, because of their high amounts of edge and screw dislocations, diffusion and partial non-stoichiometry, still imply several limitations in their use in the field of positron moderation. The second PAS study was carried with the goal of determining the best possible annealing parameters for the ELI-NP converter-moderator material. The best positron diffusion length, $L_+ = 173 \pm 4$ nm, was obtained for the sample annealed at 1100 ºC in air for 1 hour.

The second part of the thesis presented in detail the positron beam pulsing system developed for the implementation of the PALS experiment. The designed system combines the most recent developments made in the field of charged particle beam pulsing in order to obtain the best possible positron pulse time compression at the target position. The optimized MATLAB simulations have proven that the time distribution of the positrons in a pulse at the target position, achieved by the designed system, is very close to a Gaussian with FWHM = 109 ps. In the second part of the chapter a detailed account on the design and simulation of the energy filter for backscattered positrons is presented.

By using the ELI-NP γ-beam with energy of up to 3.5 MeV and intensity of $2.4 \times 10^{10}\ \gamma\ s^{-1}$, the slow e^+ beam can be obtained with a maximum intensity of $\sim 2 \times 10^6\ s^{-1}$ with platinum convertor-moderator. Solid neon moderation is applicable, and a successful implementation will result in a slow e^+ beam of intensity > $10^7\ s^{-1}$. A successful implementation of the presented positron spectroscopy laboratory will prove beneficial for the scientific community, as there is a growing interest in the study of advanced materials.