Contribution ID: 47 Type: 海报展示

用于中子毒物浓度在线测量的光中子源设计

摘要

本文针对乏燃料后处理流程中子毒物浓度在线测量的需求，设计了一种基于 7 MeV 小型电子直线加速器的脉冲光中子源技术方案。通过蒙特卡罗模拟，设计了铍中子转换靶的结构（Φ160 mm×40 mm 圆柱体），优化了其与待测溶液的相对位置，使单位流强产生的进入待测溶液的中子数达 1.4×10-5 n/e。模拟结果表明该光中子源的单脉冲中子产额达 9.3×107 个，其中能量在 1 MeV 以下的部分占 89%，在典型浓度的中子毒物溶液中发生辐射俘获的份额达 17.8%；在加速器出束脉冲期间进入待测溶液的中子占比达 94.7%，由于源的展宽引入的中子存活寿命测量偏差不大于 1.12%。光子转换靶和中子转换靶的温度和应力水平均处于安全使用范围内，满足长期稳定运行的要求。本设计为中子毒物浓度在线测量提供可行的中子源，具有良好的应用前景。

关键词

中子毒物浓度；光中子源；铍靶；中子存活寿命

Abstract

This paper proposes a design scheme for a photoneutron source based on a compact 7 MeV electron linear accelerator, which addresses the need for the online measurement of the neutron poison concentration. The structure of the beryllium neutron conversion target is designed as a Φ160 mm × 40 mm cylinder, and its position relative to the solution to be measured is optimized through Monte Carlo simulations, so that the number of neutrons entering the solution per unit flux reaches 1.4×10-5 n/e. Simulation results show that the photoneutron source achieves a single-pulse neutron yield of 9.3×107 n/s. The proportion of neutrons with the energy below 1 MeV accounting for 89% of the total, of which 17.8% will undergo radiative capture in typical gadolinium solutions. The proportion of neutrons entering the solution to be measured during the accelerator beam pulse period is 94.7%, and the deviation of neutron lifetime measurement caused by the broadening of the source is no more than 1.12%. The temperature and stress levels of the target materials are within the safe range, thereby satisfying the criteria necessary for ensuring long-term stable operation. This design provides a feasible neutron source for the online measurement of the neutron poison concentration, thereby demonstrating its promising application potential.

Keywords

neutron poison concentration; photoneutron source; beryllium target; neutron lifetime

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Session Classification: 海报展示

Track Classification: 海报展示: 海报展示