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Abstract:

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Title: **Investigation of the energy structure of the lutetium atom in the context of potential applications in metrology and quantum engineering**

This presentation reports on a comprehensive analysis of the energy structure of the lutetium atom, with the emphasis on its potential applications in quantum engineering and metrology.

The quantum nature of matter often manifests itself in the low-temperature regime, with the Bose-Einstein condensate (BEC) being an excellent example. It is a quantum material that reveals the secrets of the quantum world on a macroscopic scale. This extraordinary state of matter is utilized for creating quantum simulators [1] and measuring very weak magnetic fields [2]. The creation of a BEC requires cooling an atomic cloud to extremely low temperatures, which can be achieved through multi-stage cooling systems – initially using laser cooling techniques, and then so-called „evaporative cooling".

The implementation of laser cooling requires detailed knowledge of an atom's energy structure and its radiative transition parameters [3]. To provide a comprehensive description of lutetium atom structure, a semi-empirical method was employed, divided into three research phases: calculation of the eigenvector amplitudes describing the atom's fine structure, determination of hyperfine splittings, and parameterization of radiative transitions [4-6].

Lutetium (Lu) is the last element in the lanthanide series, occurring in nature only as a single stable isotope, ^{175}Lu. Its relatively simple electron shell structure offers a unique opportunity to conduct precise and reliable theoretical investigation of its electronic properties. The results of semi-empirical calculations provided extensive data on transition probabilities, which are crucial for evaluating the feasibility of laser cooling and allow for estimation of the contribution of undesired, so-called „leaking transitions". Additionally, high-resolution spectroscopic measurements of the hyperfine structure for levels involved in cooling transitions were conducted using laser-induced fluorescence (LIF) [7].

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