^{229}Th and ^{232}Th Optical Spectroscopy System for Nuclear Frequency Standard

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The results are presented on the comparison of different techniques of producing thorium ions: from solid $Th(NO_3)_4$ and ThO_2 compounds by the laser ablation, from a nitrate solution of ^{229}Th and ^{232}Th by inductively coupled plasma mass-spectrometry (ICP-MS), and also from a metallic thorium by the electron-beam evaporation. It is known that it is possible to use the pulsed laser deposition technique as a source of thorium ions. However, the laser ablation technique is ineffective in the case of radioactive ions (^{229}Th) placed in a solution of low concentration (10-1000 ppt), and ICP-MS technique is more appropriate. It was also found experimentally that the method of electron-beam evaporation with electron impact ionization is the most effective one for producing of triply charged $^{232}Th^{3+}$ ions. Preliminary studies show that using this method the proportion of $^{232}Th^{3+}$ ions relative to $^{232}Th^{2+}$ and $^{232}Th^{+}$ ions is 10% and 1%, respectively, which is much greater compared to the laser ablation technique. The electron-beam evaporation technique provides a basis for the high-resolution optical spectroscopy system which is developed at MEPhI, Department of Physical and Technical Problems of Metrology, and allowing for the high-precision research of optical and nuclear isomeric emission and absorption spectra of ^{229}Th isotope (Fig. 1). This system allows to perform the following tasks:

- to form a mass selective beam of singly and triply charged $^{229}Th^{n+}$ and $^{232}Th^{n+}$ ions with a mass resolution of better than 1 amu;
- to capture and hold multiply charged $^{229}Th^{n+}$ and $^{232}Th^{n+}$ ions coming from the mass selective ion source with an energy between 1 to 500 eV, in RF quadrupole linear ion trap;
- to cool the trapped $^{229}Th^{n+}$ and $^{232}Th^{n+}$ ions in a buffer gas atmosphere to room temperature;
- to proceed to the high-precision research on optical and nuclear isomeric emission and absorption spectra of ^{229}Th isotope.

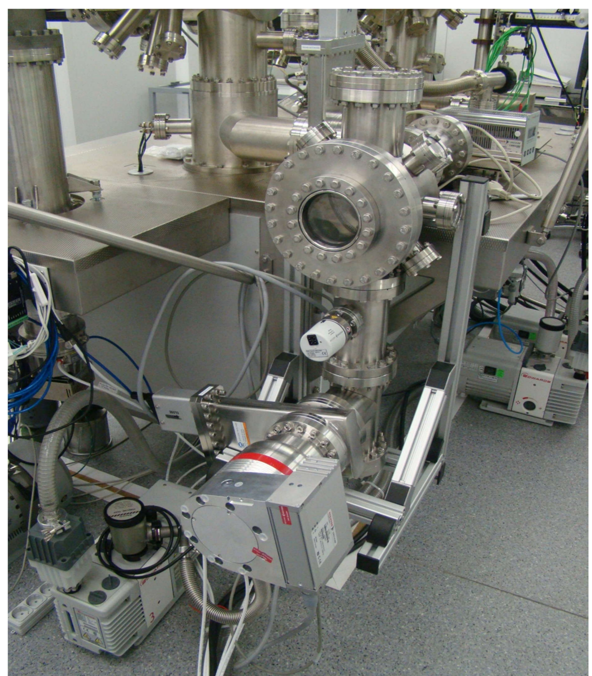

Fig. 1: Ultrahigh-vacuum installation of the optical high-resolution spectroscopy system as a separate element of the unique facility Multiprobe MXPS (Omicron Ltd. Germany) for surface research