様　式　C－19、F－19－1、Z－19　（共通）

科研費 KAKENHI

科学研究費助成事業　　研究成果報告書

令和　５ 年　５ 月 １０ 日現在

機関番号：８２１１８
研究種目：基盤研究(C)（一般）
研究期間：2019～2022
課題番号：１９Ｋ０３８９９

研究課題名（和文）Offline source of metal ions produced by ultraviolet light emitting diodes

研究課題名（英文）Offline source of metal ions produced by ultraviolet light emitting diodes

研究代表者
ＳＣＨＵＲＹ　Ｐ．Ｈ（Schury, Peter）

大学共同利用機関法人高エネルギー加速器研究機構・素粒子原子核研究所・研究機関講師

研究者番号：３０４６２７２４

交付決定額（研究期間全体）：（直接経費）　　2,000,000円

研究成果の概要（和文）：宇宙で最も重い元素の起源を理解するには、プラチナに近い元素の重い同位体の原子核を結合するエネルギーを正確に知る必要があります。 質量依存の異常は、測定に系統的な誤差を引き起こす可能性があります。 核は通常、A～200の質量を持ち、q=2の電荷で送達されるため、質量対電荷比はA/q～100になります。 ただし、当社の標準オフライン参照イオンのA/q=87およびA/q=133は、どちらも対象の種からかなり離れています。 そこで私たちは、紫外発光ダイオードを使用して原子から1つの電子を励起して除去することにより、安定した白金族元素の単純なオフラインイオン源を作成することを試みました。

研究成果の学術的意義や社会的意義
The ability to more accurately measure the masses of exotic nuclides will lead towards answering two major outstanding questions: how were the heaviest elements (thorium and uranium) created in the universe and do natural mechanisms allow for the production of superheavy elements?

研究成果の概要（英文）：In order to understand the origins of the heaviest elements -- thorium and uranium for instance -- in the universe, it is necessary to precisely know the energies that bind nuclei of heavy isotopes of elements near platinum. To make such measurements with high accuracy requires use of reference ions with nearly the same mass-to-charge ratio as those under study, otherwise mass-dependent anomalies can cause systematic errors in the measurement. The aforementioned nuclei typically have a mass of A~200 atomic units and are delivered to our spectrometer with a charge of q=2, resulting in a mass-to-charge ratio of A/q~100. However, our standard offline reference ions have A/q=87 and A/q=133, both of which are rather far from the species of interest. So, we have attempted to produce a simple offline ion source of stable platinum group elements -- Pt, W, Re, and Ir -- by using ultraviolet light emitting diodes to excite and remove one electron from the atoms.

研究分野：Mass spectrometry

キーワード：ion source

様　式　C－１９、F－１９－１、Z－１９（共通）

１．研究開始当初の背景

We have long used lasers with wavelengths ν_1~270 nm and ν_2~365 nm to ionize atoms from a thermal vapor produced inside the argon-filled KISS gas cell.　It seemed reasonable that the recently available deep UV LEDs would be able to similarly ionize atomic vapors, if somewhat less selectively than with lasers.

At KISS we produce exotic nuclei near N=126 with the goal of measuring their half-lives and atomic masses.　The atomic masses are measured using a multi-reflection time-of-flight mass spectrograph (MRTOF).　The MRTOF alternates between measuring the exotic nuclei analytes and measuring stable reference ions.　If the reference ion is sufficiently similar in mass to the analyte ion, then mass-dependent systematic errors are small and the atomic mass can be accurately determined with $\delta m/m<10^{-7}$.

These data can be used in network calculations to help understand the production of the heaviest elements in astrophysical rapid neutron capture events.　To measure the atomic masses we make use of reference ions, but have been limited in the available masses from reference ions.

２．研究の目的

To achieve the accurate high-precision mass measurements we would ideally like to have isobaric reference ions.　Lacking that, to have a reference ion with an atomic mass differing from the analyte by only one or two atomic mass units would be acceptable. We know that use of reference ions with large mass difference from the analyte (more than 5%) can cause the measurement to suffer significant systematic errors.　Standard thermal ion sources are limited to alkali species with masses of A={23, 39, 41, 85, 87, 133} which leaves large gaps.

We wanted to fill in the gaps by ionizing metal atomic vapors similar to what is done in the KISS gas cell, but without the need for large lasers.　It was desirable to have an inexpensive (compared to the lasers) means to do this for production of reference ions for use in measurements of N~126 nuclides.　This project was intended to allow us to fill those gaps and to extend the reference masses to A>200.

３．研究の方法

We have obtained filaments of various metals from which to produce atomic vapors in the reference ion production chamber. We also obtained a variety of deep UV (n_1~270 nm) and UV (n_2~365 nm) LEDs and fabricated printed circuit boards for use in the reference ion production chamber.　Unfortunately, the deep UV LEDs are proved to be inefficient and prone to overheating; producing 1 mW of light at 275 nm results in as much as 1 W of heat dissipation.　In vacuum, such heat dissipation quickly leads to the LEDs desoldering itself from the printed circuit board.　With standard FR4 circuit boards, it also quickly leads to the reference ion production chamber becoming very dirty as the circuit boards partially evaporate along with the soldering.

In the last weeks of the budget we finally obtained new aluminum substrate printed circuit boards and very high power LEDs for use in this effort.　The new circuit boards will wick the heat away to the be dissipated by the support structure.　It is hoped that following the winter 2023 online machine schedule we will be able to install and test these new aluminum circuit boards.

４．研究成果

Thus far we have not had any meaningful success in this effort.　However, we were finally able to receive high-efficiency, high-intensity 275 nm LEDs and the aluminum substrate circuit boards that could allow them to be used without overheating. As we need these reference ions for ultra-high precision mass measurements, we will continue the effort in the out years of the funding. We remain hopeful that in the next year we can finally achieve success.

５．主な発表論文等

〔雑誌論文〕　計0件

〔学会発表〕　計0件

〔図書〕　計0件

〔産業財産権〕

〔その他〕

－

６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関