論文 / 著書情報
Article / Book Information

題目(和文)	Xe原子EDM探索のための核スピンメーザーを用いた共存磁力計の研究
Title(English)	Study of spin maser comagnetometry for the Xe atomic EDM experiment
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	基礎物理学　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　理学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Existence of an electric dipole moment (EDM) of a particle directly implies CP violation under the CPT theorem. Since the contributions from the standard model (SM) of elementary particles are extremely small compared to those from the physics beyond the SM, the EDM provides a clean probe for physics beyond the SM. In this thesis, aiming to improve the current experimental upper limit for ^{129}Xe atomic EDM, an experimental scheme using nuclear spin masers with an artificial feedback was developed for a comagnetometry. In order to eliminate the systematic errors arising from fluctuations and drifts in the magnetic field, the introduction of comagnetometry was essential in precision measurement of the EDM (chapter 1).

In chapter 2, the mechanism and theoretical accounts of the spin-exchange optical pumping of the noble gases are described firstly. And then the maser equations of the several types of the spin masers including the artificial feedback maser are introduced. The principle of the optical spin detection is also described.

In chapter 3, the apparatus for the maser experiments are introduced. Firstly, the property and fabrication procedure of the maser cells are described. The dependence of the performance (relaxation time and polarization) of the cell on the cleaning procedure, material and geometry of the cell and partial pressures of the gases are studied. In order to improve the long-term stability of the masers, several new experimental apparatuses were introduced. A large three-layer magnetic shield and a static field coil were newly installed in order to improve the field homogeneity and stability. The operation temperature of the maser was stabilized by introducing a feedback control and, as a result, the root mean square (rms) deviation of the temperature of 0.0065± 0.0013 ◦C was achieved in a 10,000 s average duration. The intensity of the laser light was stabilized and its rms deviation of 1.7×10^{-2}% was realized in a 10,000 s average duration.

In Following chapters, the developments and performance investigations of the two types of the comagnetometry were described. First, an operation of the ^{3}He comagnetometry with a double-cell geometry was reported. The dependences of the maser frequencies on the operation parameters (magnetic field, temperature of the cell, and intensity and frequency of the lasers) are studied (chapter 4). By integrating the developments stated in chapter 3, the rms deviation of the 5,000s-averaged ^{129}Xe/^{3}He maser frequency was obtained to be 1.6 μHz. At the same time, however, in the view of the significant difference in magnitudes of the frequency shifts caused by contact with spin polarized Rb atoms, we conclude that essentially no significant improvement further in the frequency precision could be expected for the ^{129}Xe/^{3}He masers (chapter 6).

In order to improve the limitation from the contact shifts, a new scheme of comagnetometry that adopts as the reference spin a neighboring odd-mass isotope of Xe, ^{131}Xe, with spin I = 3/2 is proposed. Since the frequency shift of ^{131}Xe spin due to contact shifts by the polarized Rb is very similar to that of ^{129}Xe spin, the difficulty in the ^{129}Xe/^{3}He comagnetometry scheme associated by the contact shifts was expected to be significantly mitigated. As a result of the study, a ^{131}Xe (I = 3/2) spin maser with active feedback was operated for the first time (chapter 5). At present, the frequency deviation of the masers caused by the fluctuation and drift in known parameters, such as the magnetic field, the temperature of the cell, and the frequency and intensity of the laser lights are estimated to be on the order of ~μHz for the ^{129}Xe/^{131}Xe comagnetometry scheme, which is at a level similar to that with the ^{129}Xe/^{3}He comagnetometry scheme. The frequency deviation originating from the drift and fluctuation of the cell temperature, which finally limited the sensitivity in the case of ^{129}Xe/^{3}He masers, proved in the ^{129}Xe/^{131}Xe case to be drastically reduced even with the single cell geometry. Also, the rms deviation of the 5,000s-averaged maser frequency difference of 1~2 μHz was obtained (chapter 6).

In summary, the operation of a ^{131}Xe spin maser with artificial feedback was achieved for the first time, and new comagnetometry scheme for the ^{129}Xe EDM measurement, which takes full advantage of the ^{131}Xe spin maser, was established. This advantage comes from the fact that it can mitigate the contact shift which limits the ultimate sensitivity of ^{3}He comagnetometry. Further improvement of the maser stability will be achieved by the improvement of the cell performance and detailed study of behavior of I = 3/2 spin maser.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).