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Annex 6

Sun Yat-sen University College Student Innovation Training Project

application

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| --- | --- | --- | --- |
| Item Number |  | | |
| project name | Frequency Stabilization System for External Cavity Semiconductor Lasers | | |
| Project manager | xs01 | contact number | 17311113333 |
| College | School of Physics and Astronomy | | |
| student ID | xs01 | professional class | Testing Professional |
| mentor | **Thibault Thomas Vogt** | | |
| Email | \*\*\*\*@mail.sysu.edu.cn | | |
| Date of Application | Automatic acquisition | | |

#### 1. Basic situation

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| --- | --- | --- | --- | --- | --- | --- | --- |
| project name | Frequency Stabilization System for External Cavity Semiconductor Lasers | | | | | | |
| Discipline | First-level subject: Physics Second-level subject: Rydberg Atomic Physics | | | | | | |
| project source | □ A. Students choose topics independently, which comes from their long-term accumulation and interest in the topic.  ■ B. From the topic selection of teachers’ scientific research projects  □ C. Students are responsible for selecting topics for projects entrusted by society and enterprises. | | | | | | |
| Application Amount | 4000.00 yuan | Project deadline | One year | Project level to be applied for | | school level | |
| principal | xs01 | gender |  | nationality |  | Date of birth | year month |
| student ID | xs01 | contact number | cell phone: | | | | |
| mentor | Thibault Thomas Vogt | contact number | Mobile: 13322866303 | | | | |
| Project Description | | This project aims to manufacture a frequency stabilization system suitable for external cavity semiconductor lasers. The main research content and expected results of the project are to stabilize the wavelength of the laser at the F=3->F=4 transition of cesium. It is planned to use appropriate spectroscopic techniques such as DAVLL or polarization spectroscopy to solve this problem. In experiments, saturated absorption spectroscopy is usually used, and the laser frequency is modulated to generate an error signal, which is fed back through phase-locked detection. In this project we will explore value-for-money solutions that require no frequency adjustment to solve the problem of frequency stability, such as DAVLL which relies simultaneously on differential phase shifting and absorption of two different polarization components of light. The project requires creative ideas and the ability to carefully design and build optical feedback systems and delicate electronic integrated devices. | | | | | |
| The person in charge’s previous participation in scientific research | | (To be filled in by the person in charge) | | | | | |
| Instructing teachers to undertake scientific research projects | | (To be filled in by the person in charge. If the project does not come from a teacher’s scientific research project, it can be filled in as blank) | | | | | |
| Instructor’s support for this project | | Teachers will provide lasers and necessary electronic instruments such as multimeters, power supplies, oscilloscopes, etc. Faculty will track the progress of the project and provide a dedicated laboratory to work on the project. | | | | | |
| Main members of the project team | Name | student ID | college | professional class | contact number | Project division of labor | |
| xs01 | xs01 | Test Academy | Testing Professional | \*\*\*\*\*\*\*\*\*\*\* | 111 | |
| mentor | Name | Job number | College/Unit | job title | contact number | e-mail | |
| Thibault Thomas Vogt | 1\*\*\*\*\*\* | Test Academy | Associate Professor | 13322866303 | ttvogt@mail.sysu.edu.cn | |

#### 2. Basis for project establishment (can add pages)

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| **1. Research purpose**  How to achieve frequency stability of lasers is an important strategic goal for precise atomic measurement and quantum information. A simple and effective method to achieve laser frequency stability is DAVLL technology. The core of this technology is to use the Zeeman effect to obtain frequency information and feed it back to the laser to adjust the frequency. Although there are many technologies that lock the frequency to the atomic reference line, DAVLL technology can still achieve high-power and frequency-stable lasers without using expensive equipment, achieving a truly ultra-high cost performance. Therefore this technique is widely used for frequency stabilization of atomic reference lines in atomic physics.  The research purpose of this project is to build a frequency stabilization module for 894nm lasers through the DAVLL method to achieve stable control of the frequency of semiconductor lasers. Compared with other methods, the DAVLL method does not rely on modulation and is not easy to introduce frequency noise. The laser frequency stabilization time is relatively long, and it can maintain lock for a long time. In addition, this method requires fewer light sources, relatively simple circuits, and the frequency stabilization system is easy to integrate.  **2. Research content**  1) DAVLL frequency stabilization principle  A magnetic field is set on the periphery of the atomic absorption chamber. The magnetic field can be generated by using a permanent magnet or a coil that passes current. The laser emits a beam of light into the atomic absorption chamber and is parallel to the direction of the magnetic field. Since the linearly polarized light can be seen as two circularly polarized beams The light is orthogonal, and the two beams of circularly polarized light have the same intensity and opposite rotation. At this time, the Zeeman effect occurs on the atoms in the magnetic field. According to the dichroism of the atoms, the atomic absorption lines rotate left and right, forming a left-handed After the polarized light σ + and right-handed polarized light σ - are shifted in opposite directions in frequency and pass through a quarter-wave plate and a polarizing beam splitter (PBS), the longitudinally polarized light directly passes through the PBS, while the transversely polarized light is refracted Take out PBS, so that you can separate two beams of orthogonal circularly polarized light, use two photodetectors to receive the two beams of circularly polarized light respectively, and then just use a differential circuit to subtract the optical signals to get the corresponding Frequency identification curve. The DAVLL frequency stabilization method does not require the addition of modulation signals, the process of obtaining the frequency identification signal is simple, the experimental system is simpler, and it does not cause additional interference to the laser frequency. The continuous tunable range is wider than that of the saturated absorption method.   1. DAVLL experimental optical path   As shown in the figure below, the DAVLL frequency stabilizing optical path consists of an optical isolator, a 1/2 wave plate, a 1/4 wave plate, a Cs atomic bubble, a coil that generates a uniform magnetic field, two PBS beam splitting prisms and two photodetectors.    Schematic diagram of DAVLL frequency stabilization optical path  The Cs absorption chamber is placed in a uniform magnetic field generated by a coil. The laser emits a beam of linearly polarized light into the absorption chamber and propagates longitudinally along the magnetic field. The spectral lines of Cs atoms will undergo Zeeman splitting under the influence of a magnetic field, and during the photon transition process, left-handed and right-handed phenomena will occur according to the selection rule. And because linearly polarized light can be regarded as two orthogonal circularly polarized lights with the same intensity and opposite rotations, the left-handed light and right-handed light in the linearly polarized light emitted by the laser shift in opposite directions in frequency. Place a 1/4 glass slide behind the Cs atomic bubble to change the wavelength of the linearly polarized light to obtain circularly polarized light. Then, after passing through the polarizing beam splitter prism PBS, the two beams of circularly polarized light with opposite rotations can be separated and detected by two photoelectric detectors. The detector PD is detected separately, and finally the corresponding frequency discrimination curve can be obtained by subtracting the two detection signals.  **3. Research status and development trends at home and abroad**  The frequency stabilization system of external cavity semiconductor lasers is an active research field at home and abroad. At home, researchers are committed to developing efficient and stable frequency stabilization methods, including grating feedback, fiber grating feedback, absorption spectrum feedback, etc. Among them, fiber grating feedback is widely used. Researchers have improved its frequency stability and tuning range by optimizing the design and preparation process of fiber grating. In addition, phase locking technology has also received attention in China and is widely used in achieving high-precision frequency stability.  In terms of foreign research, researchers are paying more attention to the use of stable frequency reference sources, such as gas lasers and atomic clocks, to improve the frequency stability and accuracy of the system. In addition, they are working on developing new tuning components and control algorithms to achieve a wider range of frequency tuning and faster stable response. The improvement of monitoring and control systems is also the focus of foreign research, aiming to achieve functions such as real-time monitoring, adaptive control and remote operation.  Generally speaking, domestic and foreign researchers are constantly pursuing higher frequency stability, wider tuning range and faster dynamic response in the research of external cavity semiconductor laser frequency stabilization system. The goal of these studies is to meet the requirements for frequency stability and tuning performance in different application fields, and to promote the application and development of laser technology in optical communications, spectral analysis, precision measurement and other fields.  **4. Innovation points and project features**  **(To be filled in by the person in charge)**  **5. Technical route, problems to be solved and expected results**   1. Construction of light path   The stability of the laser plays a vital role in the success of atomic physics experiments. Therefore, the working state, operating temperature and current stability are core and important parts of the entire project. Therefore, based on the above reasons, we need to conduct detailed research and purchase on the relative alignment of the optical path design, the selection of laser diodes and lenses to ensure that they can achieve a well-adapted working condition.   1. magnetic field stability   The DAVLL frequency stabilization method has high requirements for the magnetic field environment. The device that generates the magnetic field is relatively strict and needs to be able to generate a uniform magnetic field, about 200G, which can be regarded as a weak magnetic field. This experiment uses a coil that passes a stable current to generate a stable and uniform magnetic field. Therefore, achieving the stability of the current is the key to the magnetic field environment state.  **6.Project research progress arrangement**  Literature review and problem understanding: 1 month Design of methods and experimental protocol: 1 month Procurement of equipment and materials: 1 month Research work: 4 months Research development: 3 months Testing: 1 month Writing report: 1 Month final demo: 1 month  **7. Already have a foundation**  (1) Research accumulation and achievements related to this project  The Rydberg Laboratory in the Quantum Information and Measurement Controls group develops atomic physics experiments, particularly related to the cooling, trapping, and excitation of cesium atoms. The Rydberg Laboratory is of particular interest in the following topics: 1) Neutral atom trapping for quantum computing. 2) Microwave light conversion for quantum communications and single microwave photon detection. It is worth mentioning that the Rydberg Laboratory has investigated and collected important knowledge and background applications regarding laser cooling and cesium atom trapping. In his recent scientific research work, Associate Professor Thibault Vogt has conducted research on atomic laser cooling and successfully published some high-level research results. Therefore, he has rich theoretical knowledge and experimental experience and can effectively guide the project.  **(2) Conditions that are already in place, conditions that are still lacking and solutions**  We have prepared theoretical knowledge and related necessary equipment for the overall success of the project.   * Wavelength meter for detecting arbitrary Rydberg state wavelengths. * Provide frequency stable main laser * A cesium atomic gas cell and a suitable photodetector.   The project involves the electromagnetic field theory in electromagnetism, the principle of refractive index in optics, and the knowledge of atomic physics. We have already studied relevant content in electromagnetism and optics. We have a solid foundation of theoretical knowledge. Through the study of mathematical methods, we are confident that we can solve most of the mathematical and physical equations involved in the research process. At the same time, our team is also willing to challenge potential difficulties in the experimental process. By studying error theory, we can scientifically find, analyze, and reduce errors. Daily experimental training has given us a rigorous scientific spirit, good experimental habits, and excellent hands-on ability, which will enable us to do tedious work such as optical path correction and parameter modification.  We will also learn relevant knowledge about atomic physics, mechanical structure and optical path construction during the winter vacation to help us better understand the project content and achieve stable frequency control of the laser. In addition, we will also use our spare time to study the experimental process of laser frequency stabilization through paper reading to make up for the lack of experimental operation experience. |

#### 3. Budget

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| **Expenditure account** | **Budget funds (yuan)** | **The main purpose** | **Funding plan released in stages (yuan)** | |
| **first half stage** | **second half stage** |
| Total budget funds | 4000.00 | buy books | 2000.00 | 2000.00 |
| 1. Business expenses | 2000.00 | none | 1000.00 | 1000.00 |
| (1) Calculation, analysis and testing fees | 2000.00 | none | 1000.00 | 1000.00 |
| (2) Energy and power costs | 0.00 | none | 0.00 | 0.00 |
| (3) Meeting and travel expenses | 0.00 | none | 0.00 | 0.00 |
| (4) Document search fee | 0.00 | none | 0.00 | 0.00 |
| (5) Paper publication fee | 0.00 | none | 0.00 | 0.00 |
| 2. Instrument and equipment purchase fees | 2000.00 | none | 1000.00 | 1000.00 |
| 3. Experimental device trial production fee | 0.00 | none | 0.00 | 0.00 |
| 4. Material fee | 0.00 | none | 0.00 | 0.00 |

#### 4. Opinions of instructors

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| **tutor:\*\*\***  **Yearmoonday** |

#### 5. Recommendations from departments

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| **Seal:**  **Yearmoonday** |