

2025年 4月 30日

YYYY/MM/DD

Fellowship ID : BR240402

独立行政法人日本学術振興会理事長 殿

To: President, Japan Society for the Promotion of Science

研究活動報告書

Research Report

1. 受入研究者/ Host researcher

受入研究機関・部局・職

Name of Host Institution, Department and Title

大阪大学・量子情報・量子生命研究センター特任教授

受入研究者氏名

Host Researcher's Name

北川 勝浩

2. 外国人招へい研究者/ Fellow

所属研究機関・部局・職

Name of Institution, Department and Title

University of Maryland, School of Medicine, Department of Radiation Oncology, Associate Professor

外国人招へい研究者氏名

Fellow's Name

Robabeh RAHIMI DARABAD

3. 採用期間/ Fellowship Period

2024年 12月 2日

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2024年 12月 31日

4. 研究課題/ Research Theme

放射線治療をはじめとする医療への量子コンピューティング応用の研究

5. 研究活動報告/ Research Report

(1) 研究活動の概要・成果/ Summary of Research Results

During my JSPS fellowship, I actively engaged in numerous productive research and academic activities, significantly fostering international collaborations between Japan and the United States in medical physics and quantum computing applications for radiation oncology.

- Discussions with Professor Kitagawa and Team:** Meetings with my host, Professor Kitagawa, were instrumental in reviewing ongoing projects and establishing future collaborations. Discussions included plans for joint NIH grant applications between the University of Maryland and Osaka University. Through these interactions, I gained valuable insights into the latest developments in quantum computing hardware, especially those at Osaka University, Quantum Information and Quantum Biology (QIQB), enhancing the practical applicability of my research on quantum computing in radiation therapy. Our collaborative work resulted in the submission of an abstract, currently under review, for presentation at the prestigious American Association of Physicists in Medicine (AAPM) Annual Meeting to be held in Washington, DC, in the summer of 2025.
- Collaboration with QIQB, Osaka University:** I collaborated closely with Professor Fujii and his research team, including Post-Doctoral Researcher Dr. Ken Okada and student Mr. Nakano. They provided critical support in

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simulating quantum algorithms, transitioning our approach from an annealing-based model to a circuit-based optimization model. This significant methodological advance has strengthened our research foundation, leading to future publications and presentations at the upcoming AAPM Annual Meeting, solidifying the partnership between the University of Maryland and QIQB.

3. **Collaboration with Sojo University, Kumamoto:** In partnership with Associate Professor Dr. Akira SaiToh, I developed innovative quantum computing-based solutions to optimize radiation oncology workflow management. We co-authored the paper "Quantum-Inspired Genetic Optimization for Patient Scheduling in Radiation Oncology," presented at the 11th QUATUO Workshop. This collaboration has already generated considerable interest and demonstrates the practical potential of quantum-inspired methodologies.
4. **Presentation at Osaka University PRIME:** PRIME at Osaka University is renowned for its pioneering work in biological digital twins using organoids, aiming to revolutionize personalized medicine and therapeutic strategies for various diseases. Having previously introduced PRIME at the JSPS Science Forum in Washington, DC, as the Chair of the JSPS Capital Region Chapter, my visit to PRIME during the JSPS fellowship allowed me to present innovative concepts linking quantum computing to digital twin applications in radiation oncology. Professor Nishida expressed enthusiasm about our approach, leading to an invitation to become a guest professor and initiating formalized collaborations. Currently, I am planning to invite Professor Nishida to serve as the host for a JSPS postdoctoral application by a candidate I recruited, further enhancing our joint research efforts in computational digital twins for personalized cancer treatments.
5. **Visited Radiation Therapy Department at Osaka University School of Medicine:** My visit to the Radiation Therapy Department provided significant insights into Japanese clinical medical physics practices, fostering mutual understanding and comparative analysis with U.S. methods. Valuable discussions enabled the establishment of a strong foundation for continued research collaborations and professional exchanges.
6. **Lecture at Osaka University:** I delivered an engaging lecture to faculty and students at Osaka University's School of Medicine, highlighting the current state and opportunities in medical physics in the United States. This interactive session sparked considerable interest, laying the groundwork for future educational and research collaborations involving students and faculty from both institutions.
7. **Collaborations with Osaka Proton Therapy Clinic:** Together with Dr. Masaaki Takashina from the Osaka Heavy Ion Therapy Center, I visited the Osaka Proton Therapy Clinic, meeting with Dr. Yuki Tominaga and Dr. Yushi Wakisaka. We conducted mutual presentations on ongoing research projects, identifying key areas of common interest. This fruitful interaction resulted in joint submissions of abstracts and papers currently under review, covering topics such as Patient-Specific Quality Assurance (PSQA) and LET-dependent Relative Biological Effectiveness (RBE) comparisons between carbon and proton therapies. Additionally, we initiated preparations for further collaborative studies aimed at PTCOG meetings.
8. **Engagement with Osaka Municipal University:** My visit to Osaka Municipal University (formerly Osaka City University) allowed me to explore the intersection of quantum biology and radiation oncology. Professors Takeji Takui and Kazunobu Sato showed interest in collaborating on a book chapter with Elsevier, promising an exciting interdisciplinary partnership to expand our collective research impact.
9. **Visit to BDOT Medical:** Exploring the integration of patient shuttle systems into radiation oncology workflows, I visited BDOT Medical's facilities in Yamanashi and Tokyo. BDOT Medical demonstrated strong enthusiasm for joint publications and potential product development, highlighting opportunities for industry-academic collaboration.
10. **Outreach with Rotary Yoneyama:** As a former Rotary Yoneyama scholar, I attended their annual meeting, delivering a speech honoring my counselor, Mr. Ueno Sadao. My presentation, prominently featured in their newsletter and on the JSPS LinkedIn page, underscored the enduring significance of international relationships and cultural exchanges between JSPS fellows and Japanese institutions.

(2) 主な研究発表 (雑誌論文、学会、集会、知的財産権等) / Main Research Publications

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1. **Research publications, under review:**

- **Robabeh Rahimi**, Akira SaiToh, Arezoo Modiri, Amit Sawant, “Quantum Computing for Optimization in Radiation Therapy Planning,” *Medical Physics Journal* (To be Submitted).
- Akira SaiToh, Arezoo Modiri, Amit Sawant., **Robabeh Rahimi**, “Quantum-Inspired Genetic Optimization for Patient Scheduling in Radiation Oncology,” (to be submitted).
- Yushi Wakisaka, Yuya Miyasaka, Yuki Tominaga, **Robabeh Rahimi**, Takeo Iwai and Teiji Nishio., “Comparative Analysis of Proton and Carbon Ion Therapy for Head and Neck Cancer: LET-Dependent α/β Ratios in EQD2 and NTCP,” (Submitted).
- Yuki Tominaga, Caroline Bamberger, Yushi Wakisaka, Masaaki Takashina, Xing Li, **Robabeh Rahimi**., “PSQA Failures in Proton Therapy: A Retrospective Analysis of Case Studies,” (Submitted).

2. **Research Presentations:**

- Akira SaiToh., **Robabeh Rahimi**., “Realistic Optimization Strategies in a Quantum-Inspired Patient Scheduler,” 11th QUATUO Workshop, Okayama, Japan, Poster, 2025.
- **Robabeh Rahimi**, Akira SaiToh, Arezoo Modiri, Yuichiro Nakano, Ken N. Okada, Satoyuki Tsukano, Baoshe Zhang, Keisuke Fujii, Masahiro Kitagawa, Amit Sawant., “First Demonstration of Prostate Radiotherapy Plan Optimization on an IBM Quantum Computer,” Abstract for American Association of Physicists in Medicine Annual Meeting, Oral, 2025. Also accepted for presentation at the University of Maryland Radiation Oncology Symposium.
- Akira SaiToh, Arezoo Modiri, Amit Sawant., **Robabeh Rahimi**, “Quantum-inspired genetic optimization tailored for patient scheduling in radiation oncology,” Abstract for American Association of Physicists in Medicine Annual Meeting, Poster, 2025. Also accepted for presentation at the University of Maryland Radiation Oncology Symposium.
- Yuki Tominaga, Yushi Wakisaka, Takahiro Kato, Masaataka Oita, **Robabeh Rahimi**, Teiji Nishio, “Improvements of Lateral Penumbra at Various Depth Regions in Scanned Proton Treatment System with a Multi-Leaf Collimator: Dose Verifications and Plan Comparisons,” Abstract for American Association of Physicists in Medicine Annual Meeting, poster, 2025.
- Yuki Tominaga, **Robabeh Rahimi**, Yushi Wakisaka, Takahiro Kato, Masaataka Oita, Teiji Nishio, “Systematic Proton Planning Study for Enhanced Lateral Penumbra Control Using Multi-Leaf Collimator and 3D Bolus,” Abstract for American Association of Medical Dosimetrist & PTCOG-NA, (submitted), 2025.

3. **Collaborative Projects in Progress:**

- Quantum Computing for Radiation Therapy Planning Optimization: Developing novel quantum algorithms to significantly improve dose optimization processes, enhancing precision in targeted radiotherapy while minimizing exposure to surrounding healthy tissue. This includes practical testing and validation on IBM quantum computers.
- Quantum Computing for Workflow Optimization in Radiation Oncology: Implementing quantum-inspired genetic algorithms tailored specifically to optimize patient scheduling and resource management. This approach aims to improve the efficiency and economic sustainability of radiation oncology departments.
- 3D Bolus Solutions for Proton Therapy: Investigating innovative 3D-printed bolus designs to enhance the treatment of superficial tumors, achieving controlled penumbra management and significantly improving the sparing of sensitive organs at risk.
- Proton Arc Therapy Development: Researching and developing proton arc therapy techniques, leveraging advanced simulation and experimental studies to enhance treatment precision, improve patient outcomes, and reduce overall treatment times.
- Neutron Measurement and Comparative Modalities: Conducting detailed neutron measurements to systematically compare neutron production across different radiotherapy modalities, evaluating their implications for patient safety and treatment efficacy.

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(3) その他/Remarks

The JSPS fellowship significantly advanced my research in medical physics and quantum computing. The supportive environment at QIQB, including special accommodations such as specialized equipment, greatly enhanced productivity and collaboration. Moreover, the JSPS Bridge program played a crucial role not only in fostering research advancements but also in expanding my professional network, initiating impactful collaborative projects, and facilitating valuable outreach activities. My profound gratitude goes to Prof. Kitagawa and the QIQB staff for this exceptional experience, which has laid a strong foundation for sustained and fruitful international cooperation.

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