International Journal on Magnetic Particle Imaging
Vol 11, No 1, Suppl 1, Article ID 2503041, 3 Pages

Infinite Science Publishing

Proceedings Article

Transmission magnetic particle optical scanning imaging

Yulong Dong[a,*] · Wenzhong Liu[a,b]

[a]School of Artificial Intelligence and Automation, Huazhong University of Science and Technology, Wuhan, China
[b]China-Belt and Road Joint Laboratory On Measurement and Control Technology, Huazhong University of Science and Technology, Wuhan, China
*Corresponding author, email: d202281101@hust.edu.cn

Abstract

Magnetic nanoparticles (MNPs) are widely used in biological magnetic imaging such as Magnetic Particle Imaging (MPI) and Magnetic Resonance Imaging (MRI) due to their unique magnetic and chemical properties. However, traditional magnetic particle imaging often comes with resolution limitations, which are typically determined by the strength of the magnetic field and the ability to spatially encode the magnetic field. To overcome the limitations of spatial resolution, we propose using optical scanning for imaging, which can achieve high imaging resolution while retaining a certain degree of penetration capability. The experimental results show that using optical scanning for MNPs imaging can achieve a resolution of 125 micron pixel size in magneto-optical signals within a 5cm · 5cm imaging range, and can penetrate 1mg/ml MNPs solution with a thickness of 1cm. The proposal of this method presents a new approach for high-precision human imaging in the future.

I. Introduction

As a medical imaging method, MPI has the advan-tages of low cost and strong penetrability, and is widely used in various tissue and organ imaging[1,2]. However, the spatial resolution of MPI signals is affected by magnetic field gradients and the properties of MNPs itself, which limits the resolution of MPI to the millimeter level at present[3]. In theory, MPI only receives magnetic signals from MNPs and lacks structural imaging of the tissue in the detection area. Therefore, traditional MPI methods cannot accurately locate relative spatial positions of MNPs.

Faced with the imaging limitations of existing MPI, we propose using optical scanning for MNPs imaging. Imaging can quantitatively detect the spatial distrib-ution of MNPs by analyzing light intensity based on the magneto-optical effect. Compared to MPI, using optical scanning methods can significantly improve imaging resolution in large fields of view. The simultaneous use of laser mechanical scanning also greatly improves the penetration depth of the sample, achieving precise positioning and concentration detection of MNPs.

II. Principle and methods

The experimental setup uses a laser as the light source and excites MNPs with a sinusoidal alternating magnetic field. The light beam passes through a two-dimensional scanning device and scans the surface of a cuvette containing the MNPs sample. At the end, a photodetector receives the light intensity transmitted through the MNPs sample. The model of the experi-mental setup is shown in Fig 1.

The materials required for the experiment include a 1 mL sample of 0.1 mg/mL MNPs and a copper wire.

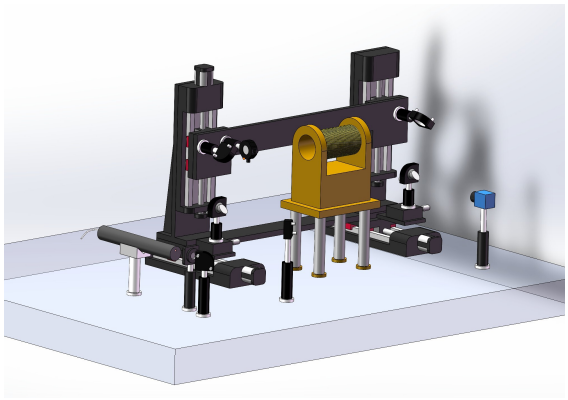

Figure 1: Magnetic Particle Two-Dimensional Scanning Optical Imaging System.

In the signal processing part, digital phase-sensitive detection technology is used to extract the second harmonic data for each pixel during the scan. In the magneto-optical gate effect[4], the second harmonic of the MNPs contains concentration information. Finally, the distribution image of the MNPs to be obtained by analyzing the harmonic intensity corresponding to each pixel.

III. Results and discussion

In this section, two sets of experimental results will be presented. The first is the harmonic intensity imaging results of the MNPs solution with copper wire, as shown in Fig 2.

Then, we will demonstrate the scanning imaging effects under different magnetic field strengths, with the results shown in Fig 3.

In Fig 2, the gray area represents the sample region, and the black slash line represent the copper wire. The arc-shaped upper part of the sample area is due to the surface tension of the liquid. From the results of the harmonic imaging, the copper wire can be clearly distinguished, and the grayscale values of the sample area represent the distribution of its concentration.

In Fig 3, we divide the magnetic field strengths during the scanning process into five regions, corresponding to 20, 40, 60, 80, and 0 Gauss, respectively. The gray-scale values of different regions reflect the magnitude of the magnetic field in the corresponding areas, which roughly show a linear relationship.

IV. Conclusion

We have developed a two-dimensional scanning optical imaging system using magnetic nanoparticles, achieving high imaging precision while penetrating through a 1 cm thick sample. After image reconstruc-tion, the harmonic intensity map clearly shows the distribution of copper wires and the MNPs within the sample. Moving forward, we will further enhance this method's ability to penetrate living tissues, aiming to apply it to human imaging in the future.

Figure 2: Harmonic intensity imaging of the MNP solution sample with a 0.5 mm copper wire placed in it.

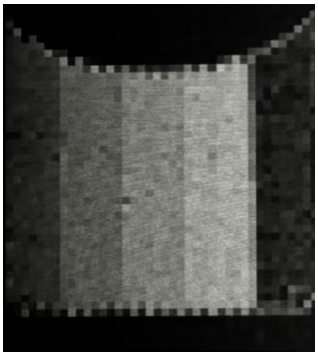

Figure 3: Harmonic intensity imaging of MNP solution samples under different magnetic field strengths.

Acknowledgments

Research funding: This work was supported in part by the National Key R&D Program of China under Grant Nos.2022YFE0107500 and 2022YFE0204700, in part by the Shenzhen Municipal Scientific Program under Grant Nos.JCYJ20200109110612375 and JCYJ20210324142004012, and in part by the Department of Science and Technology of Hubei Province under Grant No. 2023BCB011.

Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study.

References

[1] Knopp T, Gdaniec N, Möddel M. *Magnetic particle imaging: from proof of principle to preclinical applications.* Physics in Medicine & Biology, 2017, 62(14): R124.

[2] Gräser M, Thieben F, Szwargulski P, et al. *Human-sized magnetic particle imaging for brain applications.* Nature communications, 2019, 10(1): 1936.

[3] Shang Y, Liu J, Zhang L, et al. *Deep learning for improving the spatial resolution of magnetic particle imaging.* Physics in Medicine & Biology, 2022, 67(12): 125012.

[4] Cui X, Lu C, Liu C, et al. *Highly sensitive detection of magneto-optical markers based on magneto-optical gate effect.* Sensors and Actuators A: Physical, 2023, 357: 114370.

10.18416/ijmpi.2025.2503041