

Workshop Medical Microtechnology, April 28th 2022

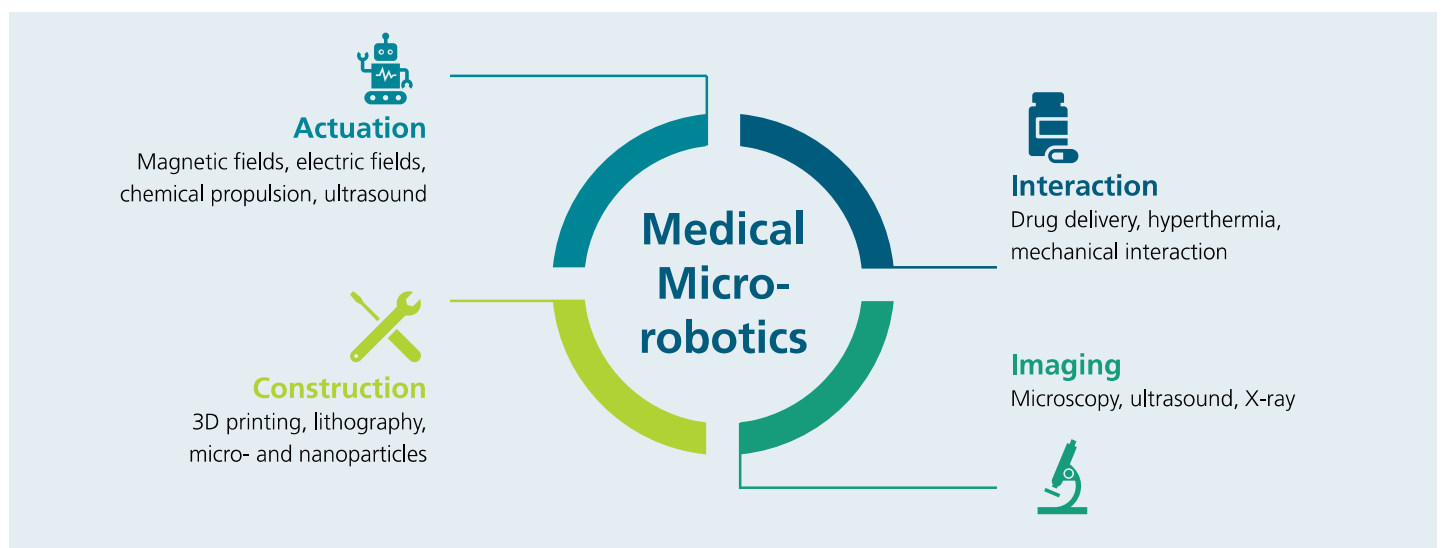
Magnetic Microrobotics meets MPI: Imaging, Applications and Vision

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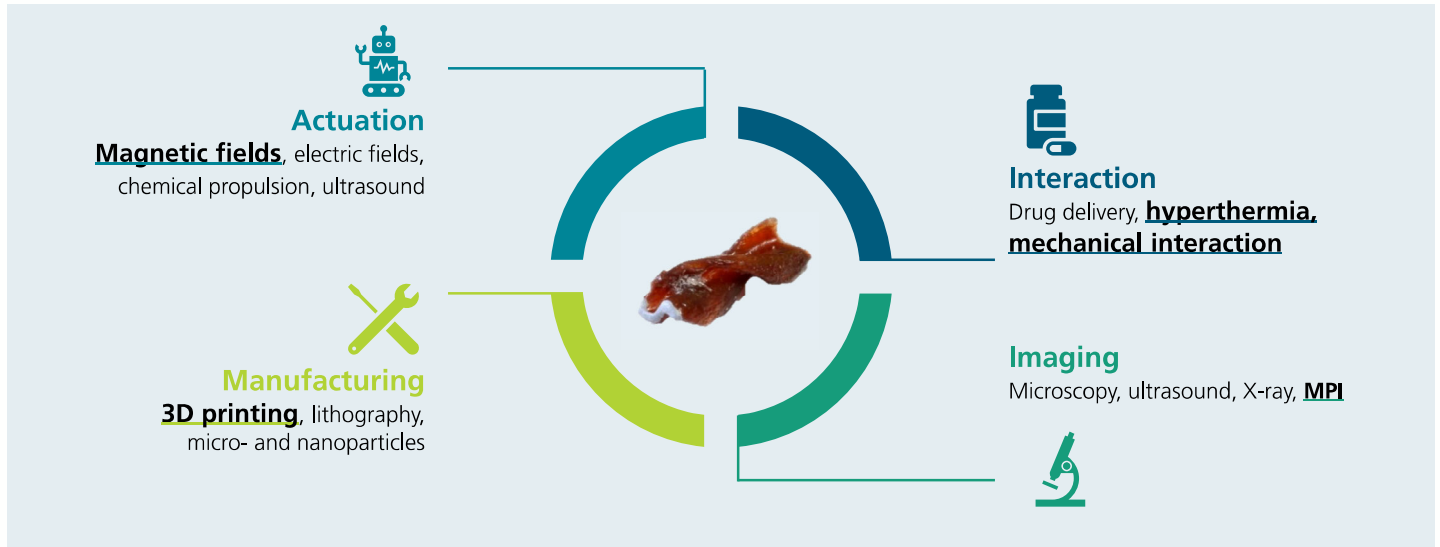
Introduction

The wide field of Microrobotics



Introduction

Microswimmer developed in Lübeck



Imaging

MPI

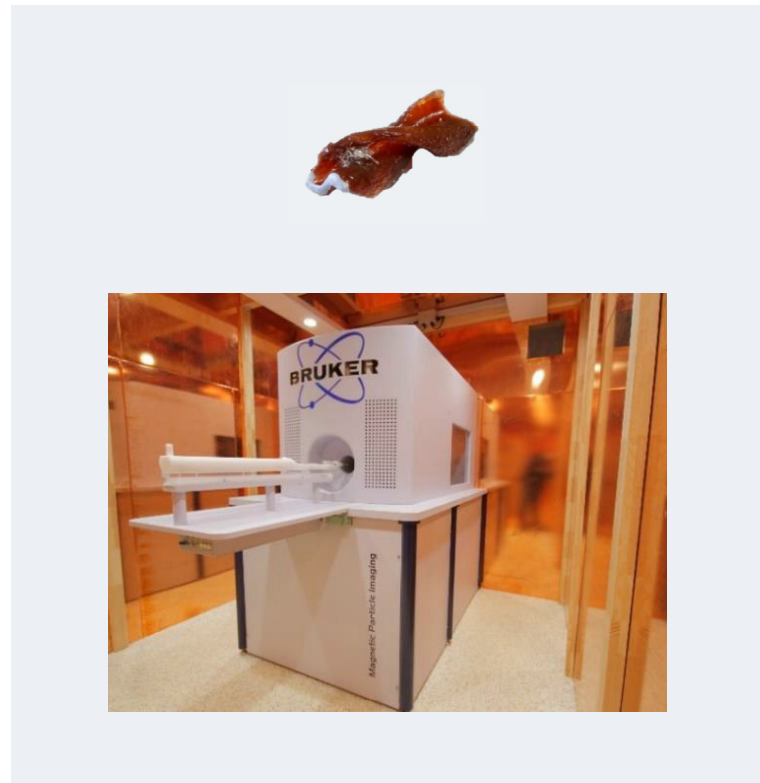


Magnetic Particle Imaging

Tomographic, real-time imaging of magnetic nanoparticles using magnetic fields

— Bruker 25/20 FF preclinical MPI system

Same field topologies as needed for magnetic actuation



Manufacturing

3D printing and magnetic coating



Basic structure printed with FormLabs Form2

Helical shape inspired by savonius turbines

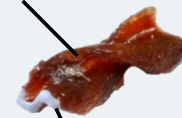
Magnetic coating with

→ superparamagnetic iron oxide nanoparticles (SPIONs)

→ NdFeB particles



SPIONs



NdFeB particles



Actuation

Steering in the imaging phantom



Magnetic fields generated by the MPI system

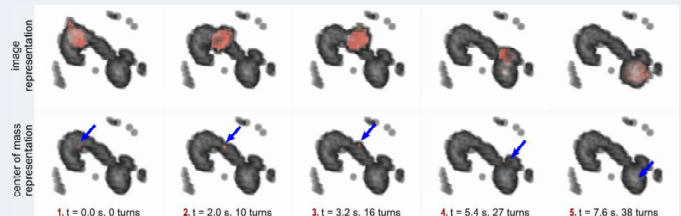
→ Homogeneous rotating magnetic fields

Pre-planned trajectory

Navigation in cerebral aneurysm phantom successful

Center of mass localization:

→ accuracy of 0.7mm achieved



Bakenecker *et al.* Navigation of a magnetic micro-robot through a cerebral aneurysm phantom with magnetic particle imaging. *Sci Rep* **11**, 14082 (2021)

Interaction

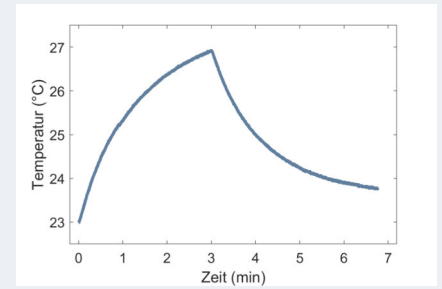
Hyperthermia



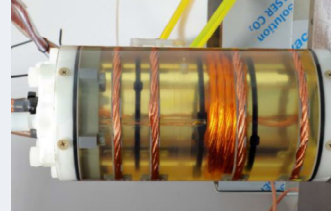
High frequency magnetic fields can heat the device

Induce coagulation and treat the aneurysm

Integration into MPI system as theranostic platform possible



Temperature increase of swimmer in experimental setup



Hyperthermia insert for the Bruker MPI

Vision for the future

Construction



Biocompatibility

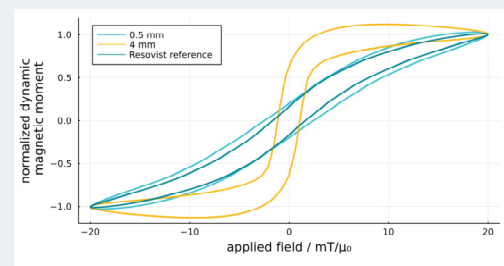
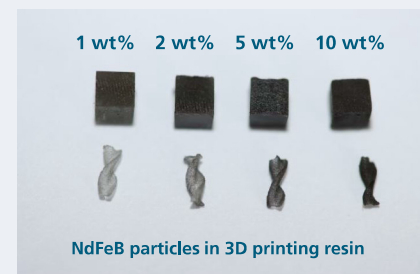
NdFeB and the used printing material are not safe

Miniaturization

Two photon polymerization enabling smaller dimensions

Smart Materials

Incorporate magnetic properties in the printing materials
Improve MPI performance with alternative materials

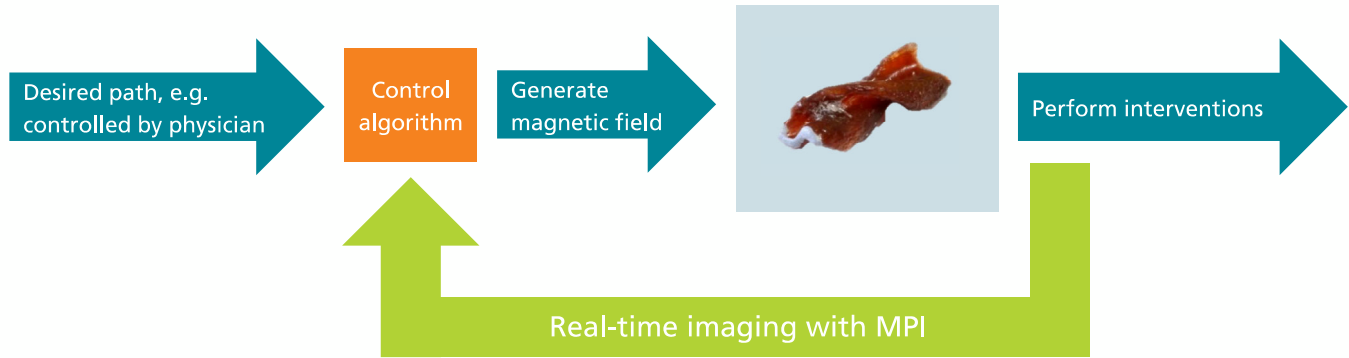


Improved MPI performance of ferromagnetic needles

Ackers et al. Printing of hard ferromagnetic materials for remote magnetic actuation. *Trans. AMMM* **2.1**, 567 (2021)
Ackers et al. MPI of soft ferromagnetic needles. *IJMPI* **8.1**, Suppl. 1 (2022)

Vision for the future

Closed loop actuation



Thank you for your attention!
Questions, please!