Application Note: Biological Effects of Large Magnetic Fields

The ability to deliver a controllable uniform magnetic field is important in a wide range of biological experiments, such as characterizing how magnetic fields influence growth and function[1], aligning magnetic nanoparticles, or studying Magnetic Field Effects in fluorescence[2].

The recently developed *FLUX* series of magnetic field sources use adjustable arrays of permanent magnets to deliver tunable, precise and highly uniform magnetic fields with strengths up to 0.3T. The *FLUX* series can operate in incubators (Fig. 1) or be integrated into microscopes (Fig. 2). The devices are easy to use, with the magnetic field adjusted simply by turning the dial. Samples can be held in the field using standard cell culture containers such as 35mm Petri dishes or Eppendorf tubes (Fig. 2).

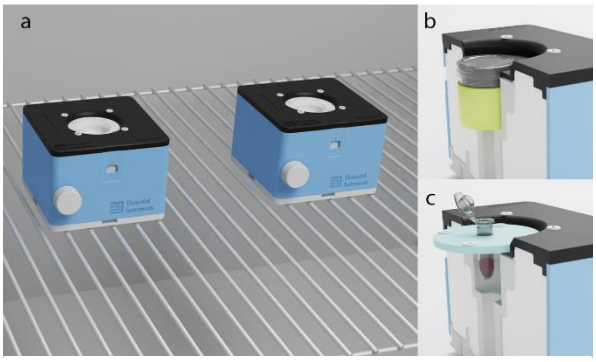

Fig. 1: (a) FLUXuni devices providing magnetic fields in an incubator. FLUX devices can fit (b) 35mm Petri dishes, or (c) Eppendorf tubes.

Unlike electromagnets, the *FLUX* series are completely unpowered except when adjusting the magnetic field, and therefore completely avoid off-target effects of excess heat generation. It is common to mitigate excess heat in electromagnets by actively cooling the coils, which costs far more and takes up more space than use of *FLUX* devices. Also, it is important to note that a magnetic field gradient has different physical effects to a uniform magnetic field. The gradient is responsible for forces that cause movement, while a uniform field causes rotational alignment and quantum phenomena such as the Zeeman effect. Generating a uniform magnetic field ensures a consistent stimulus through the sample, and allows any effect of the magnetic field gradient to be separated from the magnetic field magnitude.

As an example, *FLUX* devices could be used to study the developmental effects of magnetic fields on cells, eggs, larvae, or biomolecule mixtures. While such effects are well established, the mechanism that underpins it is unknown, with much research investigating the radical pair mechanism as a potential explanation[1]. Most research uses moderate magnetic fields, up to a few tens of mT[1]. *FLUXuni* would allow use of larger magnetic fields to characterize the biological effects more thoroughly, and to determine if the observed effects increase as expected with the field magnitude.

Alternatively, *FLUX* devices installed in microscopes (Fig. 2) could allow real-time characterization of cellular function in large magnetic fields. Magnetic fields can also influence the generation of fluorescence, including cellular autofluorescence[2]. Such Fluorescent Magnetic Field Effects could be characterized with FLUXmoto in a similar way, but without requiring a costly cooled electromagnet while allowing 7-fold larger fields.

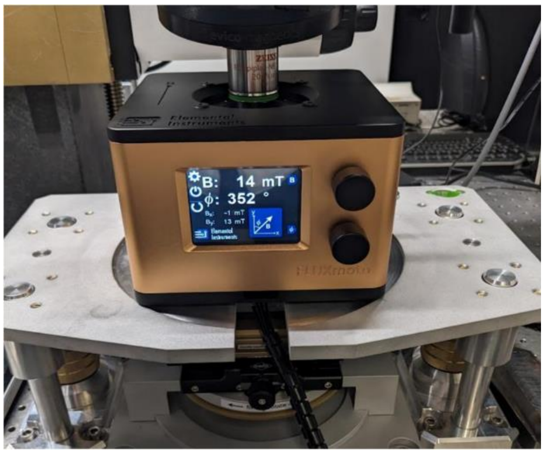

Fig. 2: A FLUXmoto unit installed in an opticl microscope.

References

1. Zadeh-Haghighi, H. & Simon, C. *J. Royal Soc. Interface* **19**, 20220325 (2022).
2. Ikeya, N. & Woodward, J.R. *Proc. Natl. Acad. Sci. USA* **118**, e2018043118 (2021).