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Technical note

'Plug and Play' assembly of a low-temperature plasma ionization mass spectrometry imaging (LTP-MSI) system

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ABSTRACT

Mass spectrometry imaging (MSI) is of high and growing interest in life science research, but the investment for necessary equipment is often prohibitive for small research groups.
Therefore, we developed a basic MSI system from low cost 'Plug and Play' components, which are connected to the Universal Serial Bus (USB) of a standard computer. Our open source software OpenMZxy (http://www.bioprocess.org/openmzxy) enables automatic and manual sampling, as well as the recording of position data.
For ionization we used a low-temperature plasma probe (LTP), coupled to a quadrupole mass analyzer. The current set-up has a practical resolution of 1 mm, and a sampling area of 100 × 100 mm, resulting in up to 10,000 sampling points. Our prototype is easy and economical to adopt for different types of mass analyzers.
We prove the usability of the LTP-MSI system for macroscopic samples by imaging the distribution of metabolites in the longitudinal cross-cut of a chili (*Capsicum annuum*, 'Jalapeño pepper') fruit. The localization of capsaicin in the placenta could be confirmed. But additionally, yet unknown low molecular weight compounds were detected in defined areas, which underline the potential of LTP-MSI for the imaging of volatile and semi-volatile metabolites and for the discovery of new natural products.

Biological significance
Knowledge about the spatial distribution of metabolites, proteins, or lipids in a given tissue often leads to novel findings in medicine and biology. Therefore, mass spectrometry based imaging (MSI) is becoming increasingly popular in life science research. However, the investment for necessary equipment is often prohibitive for small research groups. We built a prototype with an ambient ionization source, which is easy and economical to adopt for different types of mass analyzers. Therefore, we hope that our system contributes to a broader use of mass spectrometry imaging for answering biological questions.

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Mass spectrometry based imaging (MSI) is becoming increasingly popular in life science research, since the localization of molecules delivers valuable information about their involvement in physiological processes [1]. Knowledge about the spatial distribution of metabolites, proteins, or lipids in a given tissue often leads to novel findings in medicine and biology [2–5]. Therefore, it is not surprising that several suppliers of mass spectrometry equipment now offer hardware and software solutions for imaging. The most common ones at the moment are Matrix-Assisted Laser Desorption/Ionization (MALDI) and Desorption Electrospray Ionization (DESI) based imaging systems [6,7]. Secondary Ion Mass Spectrometry (SIMS) shows great potential for submicron resolution analysis of biological tissues, although the technical requirement for high vacuum might affect the sample integrity [8]. Currently there is also strong interest in developing ambient ionization techniques for MSI, because they could assist the 'bed-side' pathology during surgeries [9,10]. Another field of application for ambient ionization MSI is the nondestructive analysis of surfaces, e.g. works of art [11]. For data handling of MSI experiments, the *.*imzML* format represents a common standard, which facilitates the data exchange between different platforms [12,13]. Further, the development of data processing pipelines is supported, which is reflected by the availability of several commercial and non-commercial software solutions, such as BioMap, DataCube Explorer, Mirion and SpectViewer [13]. However, when an existing spectrometer needs to be upgraded for imaging – with limited economical resources, of course – the options are scarce.

Recently, we developed a new probe design for low-temperature plasma (LTP) ionization [14]. This ion source type has some inherent advantages, such as low thermal stress for the sample, solvent-free analysis and the direct detection of volatile compounds [15] Additionally, the construction of such a probe is surprisingly economical and easy. In order to perform ambient mass spectrometry imaging (MSI) experiments with this LTP probe, we decided to develop our own sampling/imaging system.

Conceptually, a mass spectrometry imaging (MSI) system consists of a mechanical carrier and motors for defined positioning of the sample, a motor controller, input devices for manual control of the sample movement, an ionization source, as well as control and data processing software (Fig. 1). The MSI unit is coupled to a mass analyzer for recording mass spectra. Following, we specify in detail, how these different MSI components where implemented.

Mechanical parts for the sample carrier were reused from a scrap Ettan MALDI-TOF Pro device (Amersham Biosciences, Uppsala, Sweden). For moving the slides in the x- and y-direction, two linear actuators L12-100-100-06-R (Phidgets Inc., Calgary, Alberta, Canada) were mounted. The motors have a max. positional error of 300 μm, a maximum speed of 12 mm/s, a stroke length of 100 mm and a peak power point of 23 N (@ 6 mm/s). The linear motors were connected to a PhidgetAdvancedServo 8-Motor controller (Phidgets Inc.), which is connected directly to a USB port. Phidgets Inc. provides libraries and code examples for various programming languages on their web page (http://www.phidgets.com/), which

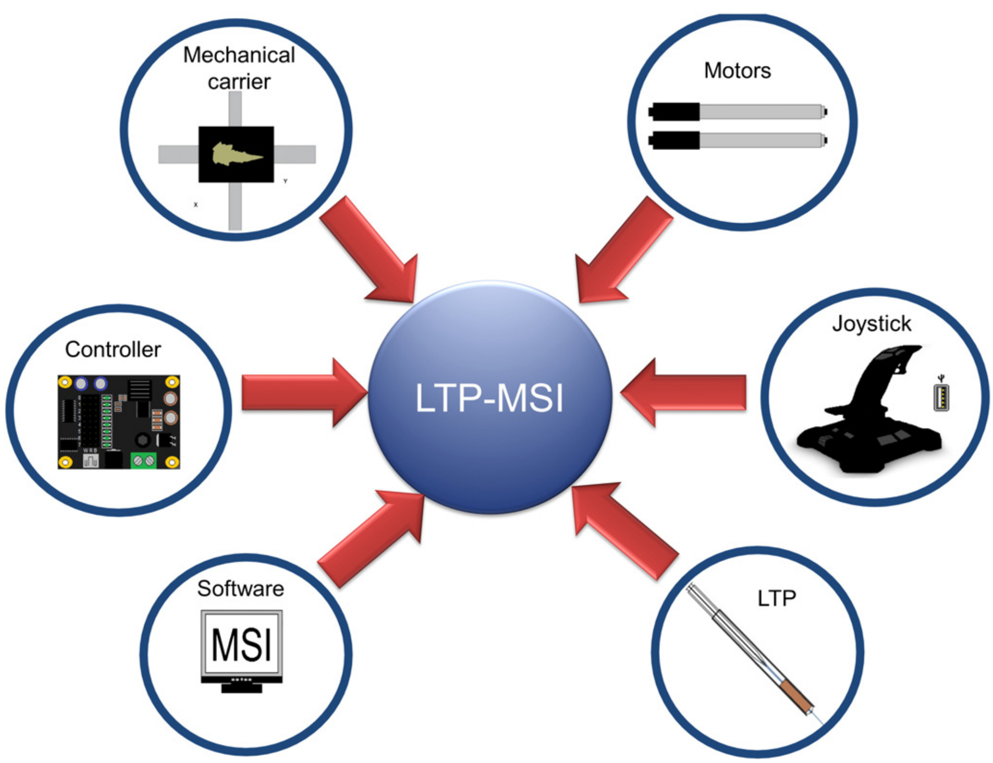

Fig. 1 – Components which need to be integrated for a low-temperature plasma ionization mass spectrometry imaging (LTP-MSI) system.