Fiber based laser interferometry stimulating the development of highly precise micro manufacturing

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In micro manufacturing, ever increasing requirements for precision and size of machined parts have, in recent years, driven the development of highest-precision machining tools. A potentially highly rewarding approach is the so called "Square Foot Manufacturing", which is based upon the standardized usage of miniaturized, modular machining units. As every unit has to be working with highest precision, the interferometric measurement of positions and angles of moveable components is of utmost importance.

The mechanical tolerances needed in metal cutting manufacturing technology have reduced significantly due to very high requirements coming from the different application fields such as medical engineering, optics, bio-technology, fluidics, and (micro-) mould and tool making. Consequently, a new research field, analogous to precision engineering has emerged, with micro-machining technologies as its main focus.

A new potentially highly rewarding approach in this field of highest precision machining is being currently developed at the Helmut-Schmidt-University in Hamburg. The Square Foot Manufacturing (SFM) concept separates well-known machining centers into small-sized sub-groups (micro machining units - MMU) that can be combined in nearly any possible way. This separation allows not only for the integration of new production methods in the future, but, due to the small dimensions of the diverse MMUs, also allows for the use of materials and technologies that have not been used in such machining centers before, hence leveraging big advantages for production. The MMUs have standardized interfaces not only for power supply and data transmission but also for the transmission of processing forces and moments.

In this respect, a new mechanical interface was developed that enables reproducible mounting and exchanging modules such as machining tools. High frequency bearing spindles driven by pressurized air, laser heads, or grinding tools of a new kind may be connected to these interfaces (see Figure 1). To measure the reproducibility of these interfaces, attocube systems' miniaturized fiber interferometer FPS3010 was employed (see Figure 2). A special differential technique allows for precise characterization of translational and rotational errors, which, in this case, are better than 0.16 µm and 8.22 arc seconds (3 sigma) respectively.

Laser interferometry also plays a key role in the feed units of this concept: Instead of traditional positioners and spindle drives, a monolithic, piezo-based design with integrated flexure hinges is employed. In this way, the system can address up to 2300 × 1015 µm². The intrinsic reproducibility of the system is about 360 nm (open-loop), yet closed-loop operation with interferometric sensors promises to bring this down to a few nanometers.

More information on „Square Foot Manufacturing" can be found at www.hsu-hh.de/laft as well as in [1-4]. More detailed documentation on attocube systems' laser based fiber interferometer „FPS3010", that was recently recognized by the R&D100 award, may be downloaded from www.attocube.com/attoMETROLOGY/introduction.html.

References:

[1] S. Grimske, N. Kong, B. Röhlig, and J. P. Wulfsberg, Square Foot Manufacturing – Advanced Design and Implementation of Mechanical Interfaces, Proceedings of the 11th euspen International Conference, Como, Italy, p. 313 (2011).
[2] N. Kong, S. Grimske, B. Röhlig, and J. P. Wulfsberg, Flexure Feed Unit – A Progress Report, Proceedings of the 11th euspen International Conference, Como, Italy, p. 331 (2011).
[3] S. Grimske, B. Röhlig, N. Kong, and J. P. Wulfsberg, Repeatable Positioning Accuracy of Mechanical Interfaces for Micro Manufacturing, Proceedings of the 12th euspen International Conference, Stockholm, Sweden, p. 209 (2012).
[4] N. Kong, S. Grimske, B. Röhlig, and J. P. Wulfsberg, Flexure Based Feed Unit for Long Feed Ranges: Concept and Design, Proceedings of the 12th euspen International Conference, Stockholm, Sweden, p. 403 (2012).

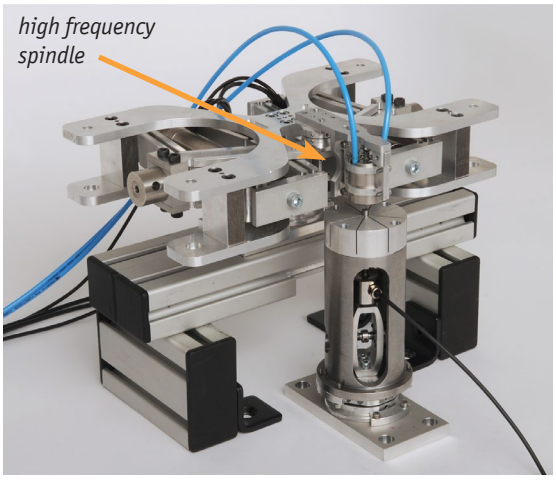

Figure 1: *Possible configuration of a micro drilling setup with a high speed spindle and miniaturized mounting brackets.*

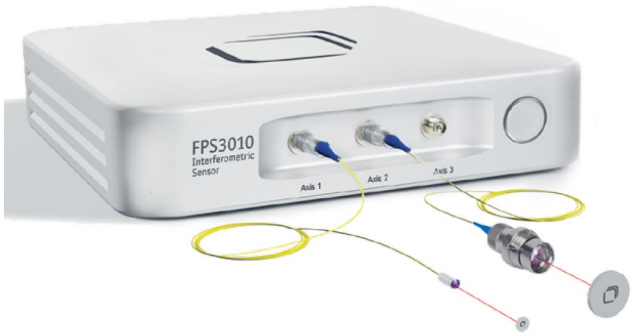

Figure 2: *attocube's 3-axes real time interferometer, the FPS3010, features 25 pm resolution and a measurement bandwidth of 10 MHz. The fiber based measurement heads are available in sizes from 4 to 14 mm diameter dependent on the application. These heads are also compatible with ultra-high vacuum as well as cryogenic conditions.*