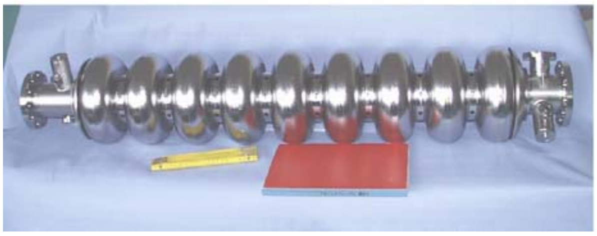
SRF 

DC field emission scanning

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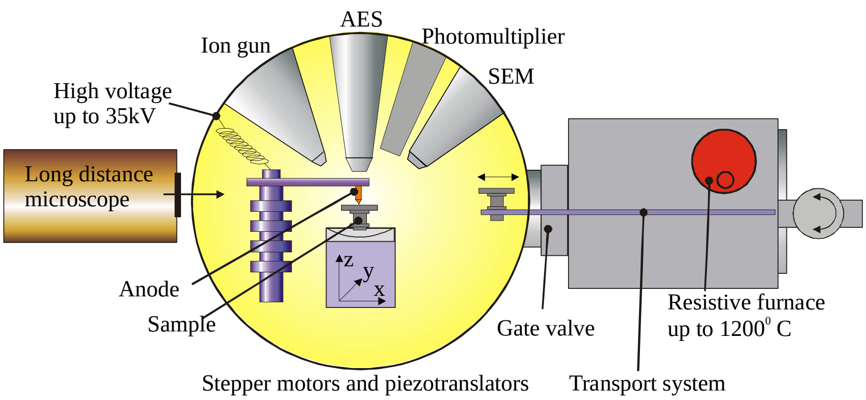
Report 2004

WP 6.3 - DC field emission scanning

I Status of activities

A new scientist, Ms. Arti Dangwal from the Indian Inst. of Technology, has been employed on July, 1st 2004 and permanently sent to Prof. Müller at the University of Wuppertal to modernize the field emission scanning microscope (FESM) and to perform the DC field emission measurements.

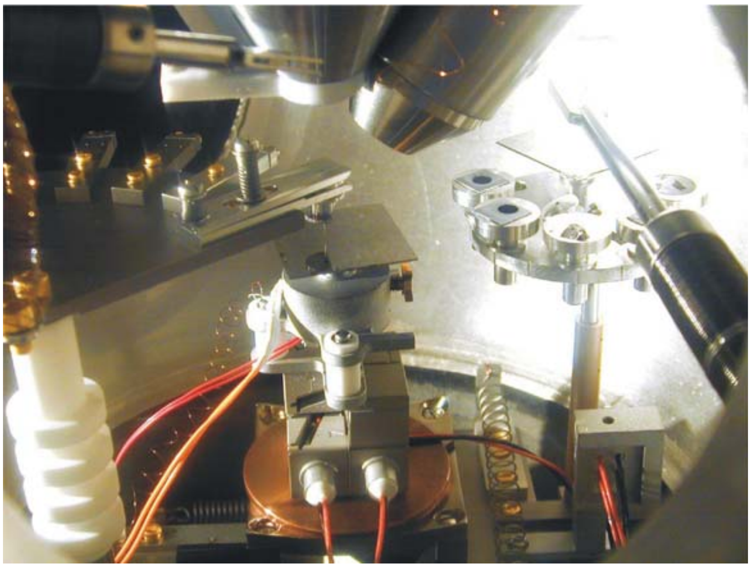


Scheme of the field emission scanning microscope (FESM)

The FESM is an advanced microscope for the localization of field emitters on flat cathodes up to 30 mm square size by zooming FE scans down to nanoscale resolution and measuring the FE properties of single emitters. It is located in the focus of an UHV surface analysis system (ESCALAB) with a base pressure of 10^{-10} mbar. In-situ SEM and AES can be used for emitter identification with about 1 µm resolution. Moreover the ion gun permits in-situ processing of emitters. The samples are installed via a linear transport system into the xyz-scanning stage of the FESM through a preparation chamber with a base pressure of 10^{-7} mbar which contains a resistive furnace up to 1200^0C (Kammrath&Weiss). By means of a separate turbomolecular pump and two gate valves, the preparation chamber also serves as a load lock with about 1 hour cycling time for sample exchange. The whole system is isolated against vibrations and ground motion.

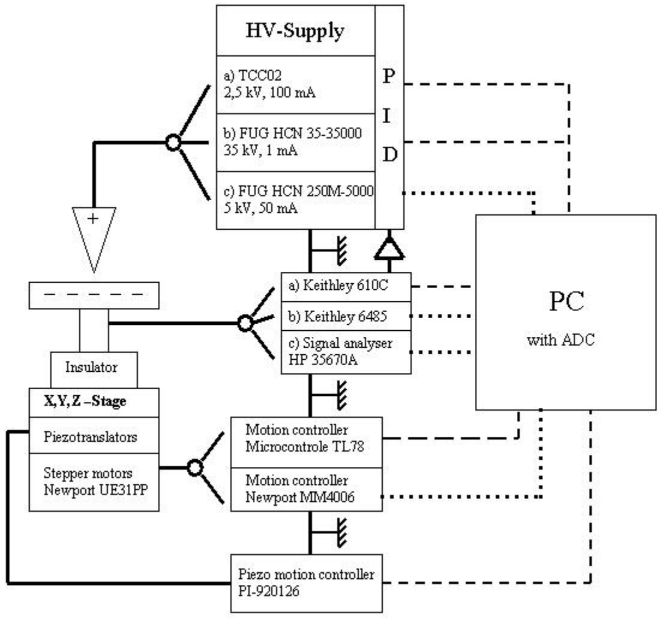
In order to change the resolution of the FE scans and local measurements, up to eight anodes can be chosen which are fixed on the rotatable anode holder. The anodes are self-made from tungsten wires either conically with 50-1000 µm diameter or needle-like with 50nm-50µm tip diameter [30]. Since the finest anodes are occasionally destroyed (e.g. by discharges) a special tip holder has been constructed which can be exchanged like samples. The sample under investigation is fixed by a screw into the xyz-stage which consists of a piezotranslator block and sliding tables inside UHV. The spacing between the anode and the sample can be monitored with µm precision by means of a long distance optical microscope (Questar) with CCD camera and the

SEM. Special care is required to guarantee a constant distance between anode and scanned area. For this purpose a tilting system has been integrated within the xyz-stage [27] which enables a tilt accuracy of ± 1 µm over 1 cm^2 and is thus sufficient even for piezo scans. Nevertheless electric field homogeneity remains difficult to achieve especially in case of rough or curved surfaces.



View into the UHV analysis chamber of the FESM. The sample (center) is assembled in the focus of the SEM, AES and ion gun (top) on the 3D piezo translator which can be tilted on sliding XYZ stages (bottom). High voltage is supplied to selectable needle anodes (left), one of which can be exchanged by the manipulator (right).

In order to increase the scanning speed for the systematic testing of numerous samples the electronic scheme of the FESM has been modernized as shown in the block diagram. Three power supplies can be chosen: a) a dc 2.5 kV source for currents up to 10 mA, b) a dc 35 kV source for currents up to 1 mA, and c) the remote controlled source up to 5 kV and 50 mA which can be pulsed with a 2 ms full height rise time. The current can be measured either with a) a dc electrometer (Keithley 610C) or b) with a Keithley 6485/E up to a rate of 1 kHz, or c) with a signal analyser (HP 35670A) for transient effects and noise investigations. The range and resolution of the xyz-stage depends on the choice of stepper motors or piezotranslators and the stability of the motion controllers. By means of a personal computer with a 12 bit four channel ADC, the FESM is usually operated in the voltage scanning mode U(x,y). For a given maximum voltage and electrode distance the location and strength of emitters are detected by the voltage drop which results from the voltage regulation loop to keep a chosen onset current (e.g. 1 nA). The maximum speed of this PID loop is limited by the capacitance of the FESM which is mainly given by the length of the coaxial cable, i.e. current slopes faster than ms cannot be detected correctly. Depending on the voltage level and PID settings, most emitters can be protected from destruction by high currents as long as the scanning speed is not too high. The programming of the stepper-motor driven xyz-stages, Keithley Picoamperemeter and FUG high voltage power supply has been completed with the LabVIEW software package, and the first FE current and regulated voltage scans will be started soon. Further programming will be required for local measurements.



Block diagram of the electric circuits of the FESM with supply connections (full), analog (dashed) and digital control lines (dotted). Please note the analog PID loop for fast voltage regulation.

A series of ten high-purity Nb samples (RRR=300) of 28 mm diameter has been fabricated and mechanically polished. A dedicated specimen holder for electropolishing, high pressure rinsing and dry-ice cleaning experiments has been constructed. First Nb samples as well as Cu samples have been prepared for quality control scans relevant for electropolished Nb and rf-gun cavities.

II Status of milestones / deliverables

According to the half-year delayed starting time only the first MS "Start of scanning activity" has been achieved. The second MS "Report on BCP/EP and DIC surfaces" will be completed in the next half-year and lead to a contribution for the Int. Workshop on RF Superconductivity at Cornell Univ. in July 2005.