Noise in Designing a Transmission Electron Microscopy Laboratory

Subjects: Spectroscopy

Contributor: Antonietta Taurino , Elvio Carlino

The proper design of a transmission electron microscopy facility is mandatory to fully use the advanced performances of modern equipment, capable of atomic resolution imaging and spectroscopies, and it is a prerequisite to conceive new methodologies for future advances of the knowledge. When quantitatively evaluating the effects of noise on TEM (Transmission Electron Microscopy)/STEM (Scanning Transmission Electron Microscopy) experiments, there are three main parameters to be considered: spatial resolution, signal amplitude, and signal-to-noise ratio. All of them can be negatively affected by the presence of external sources of noise, whose removal is crucial for TEM/STEM experiments to exploit the highest instrumental performance and capabilities. All noise sources of interest and relevant mitigation approaches are analyzed in detail.

transmission electron microscopy (TEM) noises

1. Sources of Electromagnetic Noise

The first mandatory action in a site where a TEM/STEM is planned to be installed is to accurately measure the external AC and DC sources of stray fields.

Considering that the equipment itself is a source of noise. Zhu et al. [1] reported that, before microscope installation and operation, the measured induced AC fields in the instrument room, in all x, y, and z directions at different heights, were below 0.005 mG, whereas after the instrument and the ancillary equipment were switched on, the average AC magnetic fields at 60 Hz increased to 0.15 mG in the z-direction and 0.08 mG in x-y directions, which means an increase by a factor 30 in the z-direction and by a factor 15 in the x-y plane.

The effects of EM noise are detrimental in many respects, as they produce scanning distortions in STEM images, aberrations in high-resolution TEM images, and loss of energy resolution in EELS experiments.

In [2], ad hoc experiments were planned and performed by the authors to measure the effects of EM noise in typical TEM/STEM experiments. By using a reference layer of $SrTiO_3$, grown on silicon, 5-unit cells thick (1.96 nm), they measured the distortion on STEM images, induced by an external AC field, generated by the current circulating in a coil one meter in diameter. Sensitivity factors to 0.5 Å/mG and 1.42 Å/mG were measured for a Tecnai F20 with a monochromator TEM/STEM instrument and for a VGHB501A UHV dedicated STEM, respectively.

Typical sources of AC fields are represented by currents lost towards ground, due to bad ground connections. These currents flow through metal conduits in the microscope room, causing the generation of stray fields [3]. These problems can be easily fixed but are difficult to isolate. Therefore, a simple way to overcome them is to remove all old wiring and to enclose new cables into electrical trenches far from the microscope, which, in addition to providing electromagnetic shielding and eliminating hazardous obstacles on the floor, prevents dust accumulation and facilitates floor cleaning. The floor tiles must be conductive and grounded to prevent electrostatic charging. Special attention must also be paid to lighting; for example, dimmable incandescent lighting must be chosen to eliminate the radio-frequency noise due to the electronics of fluorescent lighting, the use of which must be limited to maintenance operations [1].

Additionally, quasi-DC fields may be generated by metal objects moving close to the microscope, which are responsible for energy shifts in the alignment of the EELS spectrometer, making the interpretation of the spectra unreliable. A shift of the order of 1 eV in the EELS spectrum can be caused by moving the iron wheels of an office chair; therefore, wooden chairs are better suited for TEM laboratories. In [4], the authors reported on a series of typical moving objects which could cause these types of problems.

A simple way to mitigate the effect of EM fields, and the eventual environmental thermal fluctuation, is to host the microscope in a large room, since the intensity of EM fields decay very rapidly with distance, and the large volume of the room behaves as a thermal buffer stabilizer.

Screening strategies for electromagnetic disturbances can be passive or active: passive shielding uses high permeability metals or metal-alloys, which are commercially available in sheets or foils of different size and thickness.

Ferromagnetic alloys exhibit good behavior since their attenuation slightly drops as frequency decreases in comparison with pure metals, such as aluminum or copper.

Typical examples of branded ferromagnetic alloys include MuMetal®, Netic®, Finemet® and Metglas®, to name a few. Among these, Mu-Metal, a nickel–iron soft ferromagnetic alloy with high nickel content (80–82%), is particularly appreciated [2][3] for its attenuating properties and for its availability in a wide range of stock thicknesses from 0.36 mm to 5 mm.

The required thickness of the shielding foil is related to the skin depth, given by $\delta = \sqrt{\frac{2}{\sigma\mu\omega}}$, where σ is the conductivity, μ the permeability, and w the frequency. The formula suggests that low frequency fields are difficult to attenuate; therefore, thicker and more expensive foils are required in this case.

Active cancellation systems consist of Helmholtz coils, running around the microscope room, and feedback wideband (including DC) sensors, which measure the magnetic field to be canceled. These systems are very effective in canceling the field at an exact point and at high frequencies, where the feedback sensor is more sensitive. They are not so efficient for inhomogeneous stray fields or stray fields produced by close sources. For example, in a small room, if the field is canceled at the gun level, it would be enhanced at the spectrometer [2]. More efficient systems, based on triaxial magnetic field compensation, have been designed for the new electron microscope at the Graz Centre for Electron Microscopy [5], by optimizing the position of the sensor and the shape of the coil, both tailored to the room geometry and interfering fields. From personal experience, sometimes it happens that strange blurring can be experienced during imaging or spectroscopic experiments. After sometimes long hunting for the noise source, it disappears by resetting the active compensation system. In **Table 1**, the strategies used by different TEM facilities to attenuate EM stray fields are reported, along with the limits required by the installation specifications and the issues experienced during the laboratory realization.

2. Sources of Thermal Noise

One of the most important requisites for TEM equipment is to maintain the surrounding environment at a fixed (around 20 °C) and stable (±0.1 °C) temperature. Temperature variations cause a drift of the specimen, of the microscope electronics, and of the mechanical tolerances in components, including microscope lenses, detectors, aberration correctors, and scan coils.

As in the case of the EM fields, the size of the room plays an important role in temperature stability, since larger spaces around the microscope will better dampen any heat spike within the laboratory. Two types of temperature control systems are commonly used, i.e., forced air systems and radiant panels; they remove heat and keep the temperature as required. Forced air systems remove heat by convection and conduction. Since the heat capacity of air is very low, large airflows are necessary to remove heat. Airflows cause air pressure on the microscope column, resulting in mechanical vibrations (see next paragraph). This is one of the reasons why, in modern laboratories, heat removal by air flow is minimized by using two more convenient strategies: the first one is passive and consists of locating all heat-generating equipment that can be separated from the microscope, such as power distribution racks in a service room, separated from the microscope room. The second one is active and is based on radiation, instead of conduction and convection, as the main mechanism for heat load reduction, by using thermal masses placed in the microscope room. Radiant panels [6][7] are installed on the room walls and chilled water is circulated through them; they can regulate the temperature to better than 0.1 °C, and, in case of thermal drifts, for example due to the entrance of a person in the microscope room, the return to equilibrium is quite rapid.

Therefore, forced air systems are minimally used to regulate the temperature and mainly to control humidity, thus avoiding water condensation on the radiant panels and on the cooled parts of the microscope (electronics, pumps).

The primary effect of using radiant panels instead of a forced air system is reduced drift of image and spectra, helpful for long acquisition times, like during the frame integration of STEM image acquisition, 4D-STEM, or during analytical experiments such as EELS and EDXS chemical mapping. Secondly, since both spectrometer and high-tension supply are sensitive to temperature changes, higher temperature stability results in more reliable spectra as a function of time.

3. Sources of Mechanical Noise

Mechanical instabilities are crucial, especially for the microscopes of the latest generation, since the presence of aberration correctors and/or monochromators makes the column longer than in old microscopes and more sensitive to mechanical vibrations. The stiffness of the microscope's column linearly worsens with height and roughly improves with the second power of diameter. Therefore, modern microscopes have been completely redesigned by manufacturers to achieve better stability. Nevertheless, environmental vibrations remain an important source of instabilities, especially at the level of the gun and the specimen. The gun is placed on top of the column and is, therefore, subjected to maximum sway, with a detrimental effect on probe formation. Stage movements are also negative for high resolution imaging and spectroscopy. Vertical vibration of the specimen within the objective lens pole pieces results in a spread of focus of the image, which limits the attainable resolution. Horizontal vibration, usually more in one direction, will smear out the image, also limiting the resolution.

One of the main difficulties related to the treatment of vibrations is the microscope's sensitivity to low frequency vibrations, in the range of a few Hertz; these are the most difficult to eliminate from the microscope's environment.

There are different sources of mechanical noise; they can be distinguished because of the medium responsible for the noise propagation, i.e., air and soil.

Mechanical noise from air is related to air movements, mainly generated by acoustic waves and thermal gradients, deriving from temperature control systems.

The temperature control systems must be designed and realized in such a way that air movements in the laboratory are minimized. Forced air systems should diffuse air as much as possible to produce laminar flow. To this aim, a technical solution is represented by a laminar ceiling made of perforated panels, which provide downward and even air distribution. This solution is quite expensive and difficult to retrofit. Another solution, much cheaper and particularly suitable for retrofit, makes use of a duct sock connected to the air inlet; the natural wave of the sock tissue lets air softly diffuse out, as reported in [2]. In [3], the authors created a home-made simple but effective test which could be easily carried out to roughly evaluate the airflow; the so-called "toilet-paper test": 12 × 0.25 inches. Strips of single-ply paper are attached around the microscope, and, if they deflect at the bottom by more than an inch, then the airflow exceeds 20 ft/min. At the time the article was written, 15 ft/min was considered acceptable for a 0.2 nm resolution in STEM, but, today, the sub-angstrom resolution achievable with the modern state-of-the-art instrument requires much lower limits, as reported in **Table 1**, and highly sensitive airflow detectors for their quantitative measurements. Nevertheless, the test can be performed as a preliminary test to assess the condition of the room, or to periodically monitor time stability.

Air movement caused by acoustic waves impacts microscope performance, depending on intensity and frequency. Common sources of acoustic noise are computers, power racks, pumps, chillers, electronics, and air inlets, but external sources can also contribute. Noise attenuation can be achieved by using acoustic shielding, and since common sound damping materials like polyurethane or other foams are inefficacious at low frequency (f < 130 Hz) where the microscope is more sensitive, an effective solution for low frequency attenuation is to use fiberglass absorbers, placed in front of the laboratory walls with an air gap in between. Nevertheless, as in the case of the EM stray fields, before applying any attenuation strategies, the most reasonable and effective approach is to identify the sources of acoustic noise and remove them, or put them as far from the microscope as possible. For example, all ancillary equipment, such as power racks, pumps, and chillers, must be isolated in a separate service room [1][8]. For acoustic noise, it is difficult to define limits and thresholds, since each microscope reacts to acoustic waves depending on its own resonances. Generally, an accredited criterium is to reduce the sound intensity below 40 dB [1], as reported in **Table 1**.

Mechanical vibrations from the floor supporting the microscope may have different origins: one is related to microquakes, caused by movements of the Earth's crust, sea waves, mountains, and even glaciers; these "microseisms" contribute to a background noise which cannot be eliminated. In [9], the authors showed plots of the micro-seismic activity near NCEM at LBNL in Berkeley recorded during a Pacific storm on 25 December 1996.

Local sources are road or rail traffic, heavy machinery, and similar items which produce vibrations in the soil, the propagation of which can reach the bedrock under the microscope. Vibrations in the low-frequency range (<5 Hz) are the most critical for the microscope; their attenuation can be efficiently achieved using large masses, i.e., by placing the microscope on a concreate slab with suitable sizes that must be tailored, after a geological inspection. To correctly dampen vibrations coming from the soil, the slab weight must be generally tens of times larger than the microscope weight; the slab must be also isolated from the remaining floor with a few cm-wide trench, avoiding the transmission of movements of the building hosting the microscope laboratory.

In addition to the use of large slabs as a passive measure to attenuate vibrations, all microscopes have their own passive air cushion (or springs) isolation systems that provide enough isolation for frequencies above 10 Hz. Furthermore, active systems are also available, which can actively compensate for disturbances in a wide range of frequencies, even in the critical range 1–5 Hz. As reported for the active electromagnetic compensator, a malfunctioning of these devices could also happen and could require a reset of the device to restore proper operation.

As for the other sources of noise, prevention, when possible, is always more effective and less expensive than mitigation. Therefore, an a priori evaluation of the possible sources of vibrations should guide the choice of site for the infrastructure to be constructed ad hoc. When possible, closeness to street traffic, elevators, and even highly frequented corridors must be avoided, as even foot fall impact must be mitigated for. In **Table 1** and **Table 2**, the technical strategies applied at different facilities to limit mechanical noise from soil are reported.

Table 1. Description of measures and strategies to mitigate the noise adopted in the electron microscopy facilities considered in **Table 2**.

Institution/Facility	Instrumentation		Noise Sources, Limits and Reduction Measures: EM Fields (mG, rms[1] Values for AC Fields)	Mechanical Vibrations from Soil (Amplitude in μm (p-p) [1], or Velocity in μm/s)	Mechanical Vibrations from Air (Airflow: m/s)	Acoustic Noise (dB)	Temperature (t: °C), Thermal Stability (s: °C/h), Humidity (h: %)
Brookhaven National Laboratory Long Island, NY, 11973 USA	**JEM2200FS TEM/STEM JEM2200MCO TEM/STEM**	**Factory Limits**	**<0.5 mG** at 60 Hz	*Not reported*	**<7.6 × 10^{-2} m/s**	*Not reported*	s: **0.1 °C/h**
		Measures adopted	EM cancellation system	→ 60-cm thick (2 ft) concrete slab, isolation gap filled with de-coupling materials → Active compensation system	→ U-shaped air-supply inlet tube covered with a small pored “duct sock” → Clamshell for sample stage	*Not reported*	*Not reported*
		Issues	→ The system can only cancel the field at one point → Non effective for small corrections (reached values 0.2–0.5 mG at 60 Hz)	Active compensation is not suitable for frequencies lower than 10 Hz	The 7.6 × 10^{-2} m/s limit is too weak for tall instruments with aberration correctors. More stringent limits are required	*Not reported*	*Not reported*
	Hitachi HD2700C Titan 80-300	**Factory Limits**	→ AC fields **<0.035 mG** at f = 60 Hz **<0.035 × (f/60) mG** at f < 60 Hz → DC fields **<1 mG** (vertical) **<0.01 mG** above earth	**<0.25 μm/s** (rms, for all directions and frequencies)	**<1.7 × 10^{-4} m/s** (vertically) **0 m/s** (horizontally)	**<40 dB**	t: **21.1 °C** s: **0.1 °C/h** h: **40–60%**

Institution/Facility Instrumentation			Noise Sources, Limits and Reduction Measures EM Fields (mG, rms[1] Values for AC Fields)	Mechanical Vibrations from Soil (Amplitude in µm (p-p) [1], or Velocity in µm/s)	Mechanical Vibrations from Air (Airflow: m/s)	Acoustic Noise (dB)	Temperature (t: °C), Thermal Stability (s: °C/h), Humidity (h: %)
			ambient field (horizontal)				
		Measures adopted	→ EM shielding of the building electrical room by Al and low-carbon steel plates → Dimmable incandescent lighting to eliminate radio-frequency interference → Conductive and grounded floor tiles to avoid electrostatic charges → All circuits enclosed in metal conduits, electrical panels with Al and steel shielding	→ 60-cm thick concrete slab with 15 cm thick top layer containing a vibration-reducing agent “Concredamp” reinforced with polypropylene fibers → 1.3 cm isolation gap between the slab and the remaining floor → Three active vibration dampers → All vibrating equipment, such as vacuum pumps and water chillers, in a separate galley	→ Acoustic blankets above the microscope’s column to blank off air flow → Ventilation to CR only by exhaust grill located at floor level at 7.6×10^{-2} m/s	→ Insulating polyurethane foam panels on the outer room walls and ceiling → Silencers installed in the air handlers of the ER conditioning system → Water flow below 0.9 m/s for piping and 0.6 m/s for radiant panels → Suitable hole size in the ceiling	→ Radiant panels on the wall and ceiling in the IR → ER conditioned with constant volume VAV box and thermally insulated with gasketed doors
		Issues	*Not reported*	*Not reported*	Residual noise at 4–10 Hz due to belt-driven equipment	*Not reported*	*Not reported*

Institution/Facility Instrumentation			Noise Sources, Limits and Reduction Measures				
			EM Fields (mG, rms[1] Values for AC Fields)	**Mechanical Vibrations from Soil (Amplitude in μm (p-p) [1], or Velocity in μm/s)**	**Mechanical Vibrations from Air (Airflow: m/s)**	**Acoustic Noise (dB)**	**Temperature (t: °C), Thermal Stability (s: °C/h), Humidity (h: %)**
Max-Planck-Institut für Metallforschung Stuttgart, GERMANY	**JEOL JEM ARM 1250**	**Factory Limits**	AC fields **<1 mG** *	**<1 μm** (rms) at resonance	**<0.1 m/s**	*Not reported*	s: ±1 °C/h s (cooling water): **<0.05 °C/min**
		Measures adopted	*Not reported*	215 tons concrete foundation suspended by pneumatic vibration isolators (resonance frequency below 1 Hz)	*Not reported*	*Not reported*	*Not reported*
		Issues	*Not reported*	*Not reported*	*Not reported*	*Not reported*	*Not reported*
One-Ångström Microscope (OÅM) Lab Lawrence Berkeley National Laboratory Berkeley, USA							
	Philips CM300UTFEG	**Factory Limits**	AC fields **<0.1 mG** * at 60 Hz	**0.8 μm/s** at 1–5 Hz **6 μm/s** above 10 Hz (horizontal, left to right)	*Not reported*	*Not reported*	s: **0.5 °C/h**
		Measures adopted	→ Power and signal cables, and all cooling-water hoses, routed in steel-covered cable trenches far from the microscope	→ Concrete isolation slab (3.3 m × 4.2 m, 1 m thick) with 2.5 cm isolation gap (vibration reduced by a factor three/four vertically, also at 1–5 Hz, and more than 10 times	→ Air inlets along the side of the room, farthest from the microscope column, providing a laminar flow down the wall and across the floor	→ Acoustic damping by 50-mm thick cloth-covered fiberglass sound absorbent on both sides of the wall separating the ER from the IR → All noisy equipment (vacuum pumps, water chillers, HT tank and	Water chiller for objective lens coil adjusted so that the temperature of the water leaving the lens is at the temperature of the microscope room

Institution/Facility Instrumentation			EM Fields (mG, rms[1] Values for AC Fields)	Mechanical Vibrations from Soil (Amplitude in μm (p-p) [1], or Velocity in μm/s)	Mechanical Vibrations from Air (Airflow: m/s)	Acoustic Noise (dB)	Temperature (t: °C), Thermal Stability (s: °C/h), Humidity (h: %)
				Noise Sources, Limits and Reduction Measures			
				in the other directions)		computers) in a separate ER. Solid-state amplifiers to extend keyboard, mouse, and monitor cables to 7.5 m. Microscope camera controllers moved from the microscope console to the ER and covered with acoustic panels → Carpet over thick rubber pad on the second floor to mitigate foot fall impacts	
		Issues	*Not reported*	*Not reported*	*Not reported*	*Not reported*	*Not reported*
The Triebenberg Laboratory Dresden—GERMANY		**Factory Limits**	AC fields **<0.05 mG * at 60 Hz.** (Note: Before microscope installation AC stray fields were 2 μG)	*Not reported*	**0.05 m/s**	**<20 dB**	**s < 0.1 °C /min**
		Measures adopted	→ Transformer at 100 m from the microscope and suitably	→ Entire Building on a 2-m thick layer of sand → Three mutually	Air-inlet through hollow floor, optimized by computer simulation	→ Air ducts covered by 2-cm thick, porous rubber → Acoustic damping systems	The room heat capacity allows to switch off the air

Table 2. Transmission electron microscopy facilities and relevant instrumentation, of which laboratory design and construction are discussed in the literature in dedicated articles or sections of articles. Here, details about the

Institution/Facility Instrumentation	Noise Sources, Limits and Reduction Measures				
	EM Fields (mG, rms[1] Values for AC Fields)	Mechanical Vibrations from Soil (Amplitude in	Mechanical Vibrations from Air (Airflow:	Acoustic Noise (dB)	Temperature (t: °C), Thermal Stability (s:

reported,

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Facility (Name/Institution and Location)	Building Construction Details	Laboratory Design	Microscope Name (Year of Installation) (Microscope Info: Maximum Voltage, Electron Optics Peculiarities, Reached Resolution)	Additional Data on Microscope Performances and Noise Shielding
Brookhaven National Laboratory Long Island, NY 11973, USA [1][10]	Completely renewed 50-year-old building (previously a gym)	*no details are given*	**JEOL JEM2200FS (2004, Jeol Ltd. Akishima, Tokio, Japan)** (200 kV Schottky FEG, probe corrected, in column energy filter, 0.12 nm information limit, HAADF STEM resolution 0.105 nm) **JEOL JEM2200MCO (2008)** (200 kV Schottky FEG, URP objective lens, monochromator, double corrected, in column energy filter, 0.1 nm point and HAADF resolution, energy resolution of the omega filter 1.0–1.1 eV at ~100 μA emission current and 0.7 eV at ~30 μA)	→ Both microscope columns based on JEM2010F design, with 25 cm diameter column. Not suitable for long corrected column (JEM2010F length 2.5 m against 3.68 m of JEM2200MCO) → Contrast dip between dumbbells in Si [110] zone axis better than 20% (for JEM2200MCO)
	→ New building on a selected 5300-acre site with few sources of vibration and EM interference → Entire building constructed on compacted structural fill, compressed to 98% maximum dry density	→ Room-in-room concept: Instrument Room (IR), Equipment Room (ER) 15 cm air gap between inner and outer walls. External room with walls and ceiling in aluminum prefabricated modules, internally	**Hitachi HD2700C (2007)** (200 kV cold FEG, dedicated STEM, probe corrected, 0.1 nm HAADF resolution, 0.35 eV energy resolution)	→ Equipped with a telephone-booth-like metal box to reduce acoustic noise and thermal drift → 24 cm column diameter → 56% contrast between Ba and background in HAADF image of $BaTiO_3$

Facility (Name/Institution and Location)	Building Construction Details	Laboratory Design	Microscope Name (Year of Installation) (Microscope Info: Maximum Voltage, Electron Optics Peculiarities, Reached Resolution)	Additional Data on Microscope Performances and Noise Shielding
		covered with 10-cm thick polyurethane foam insulation panels. → Control Room (CR) with double-glass panels for viewing the microscope room → Separated 3-m galley for all vibrating equipment (vacuum pumps and water chillers)	**Titan 80-300 (2007)** (300 kV Schottky FEG, image Cs corrector, environmental TEM, 0.07–0.08 nm information limit, 0.66 eV energy resolution at 300 kV)	→ 30 cm column diameter specifically designed for mechanical and thermal stability → Contrast dip between dumbbells in Si [211] zone axis of about 20%
Max-Planck-Institut für Metallforschung Stuttgart, GERMANY [11]	Newly designed and constructed room		**JEM ARM 1250 (1994)** (1250 kV, thermionic LaB_6 cathode, 0.105 nm point resolution, 0.085 nm information limit)	→ High voltage stability: $<10^{-6}$/min p-p → Objective lens current stability $<6 \times 10^{-7}$/min p-p → Specimen drift ≤ 0.004 nm/min → ΔE: 0.6–1.6 eV depending on the operation and acquisition conditions
One-Ångström Microscope Lab (OÅM) Lawrence Berkeley National Laboratory Berkeley, USA [8][9][12][13][14]	Newly designed and constructed building	→ IR and separated ER for all noisy ancillary equipment. Walls between IRs and back rooms up to the base of the second floor to ensure acoustic separation.	**Philips CM300UTFEG (2001)** (300 kV, Schottky FEG, HREM resolution 0.089 nm, 0.078–0.080 nm information limit, 0.85 eV gun energy spread)	→ Improved information limit from 0.107 to 0.078 thanks to the high-stability of the power supplies, and hardware corrector for three-fold astigmatism → Sub-Å resolution can be accessed (in the absence of a TEM Cs-corrector) using the focal-series

Facility (Name/Institution and Location)	Building Construction Details	Laboratory Design	Microscope Name (Year of Installation) (Microscope Info: Maximum Voltage, Electron Optics Peculiarities, Reached Resolution)	Additional Data on Microscope Performances and Noise Shielding
				reconstruction (FSR) technique
The Triebenberg Laboratory Dresden, GERMANY [8][15]	Laboratory designed and constructed from the outset on a site selected ad hoc for its peculiarities of isolation and distance from populated areas	→ Two buildings, one for media supply, power control and conditioning system, the other for microscopes → Microscope building with six microscope units, each consisting of a microscope room, a room for peripheral devices (power supply, computers, cooling units), and an office → Room-in-room design with the interior walls of the IR 36-cm thick, at 10-cm separation from the external walls, and on a separate foundation	**Philips CM30FEG UT/Special-Tübingen TEM (2000)** (200 kV Schottky FEG, point resolution 0.165 nm (5.9 nm^{-1}), information limit 0.091 nm (11 nm^{-1}))	The spatial resolution of the CM30FEG improved from 1.2 Å to 0.9 Å when re-sited in the Triebenberg Laboratory
Advanced Microscopy Laboratory Oak Ridge National Laboratory Oak Ridge, Tennessee, USA [8][13][16][17]	→ New specially designed building → Building with “house-in-house” design. External walls with 12-inch concrete blocks and internal room walls with 8-inch concrete blocks → “Slab-on-grade” foundation, with instrument room	→ IRs separated from CR and sharing an acoustically isolated common chase, for all ancillary equipment, except water chillers → IR floor slabs (1′ thick, and the full area of the room) isolated from the CRs, corridors and	**JEOL JEM 2200FS (2004)** (200 kV Schottky FEG, probe Cs corrected, in column energy filter, information limit 0.085 nm, energy spread from 1.3 eV down to 0.7 eV depending on the gun conditions) **VG HB-501 (2004)** (Dedicated probe Cs corrected STEM)	(Data relevant to JEOL JEM 2200 FS) → Operated solely via remote computer control, no standard viewing chamber with fluorescent screen provided → Measured HT voltage stability of 0.6 × 10^{-6} (rms) and OL current

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Facility (Name/Institution and Location)	Building Construction Details	Laboratory Design	Microscope Name (Year of Installation) (Microscope Info: Maximum Voltage, Electron Optics Peculiarities, Reached Resolution)	Additional Data on Microscope Performances and Noise Shielding
	slabs and wall footings on a previously prepared site comprising several layers of “engineered fill” (to a depth of 8 feet) separated by layers of a “geotechnical fabric” material that together provide a stable, uniform base for the laboratory	service chase Access to CR through a vestibule and an air lock access slot (space) → Isolated mechanical building (200 feet from the microscope suite) for dedicated 75 kVA power supply unit, air handling systems, water chiller units, each supported on separate slabs → Separate control of airflow and temperature for each area	**VG HB-603UX (2004)** (Dedicated probe Cs corrected STEM, 0.05 nm nominal resolution)	stability of 0.25 × 10^{-6} (rms) giving a defocus spread of 1.85 nm and an information limit of 0.085 nm → Just after the installation, due to bad environment conditions, scarcely resolved dumbbell spacings of 0.136 nm in Si [110] similar to the same instrument without Cs aberration corrector

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