

# Advanced Materials Characterization Laboratory at Oak Ridge National Laboratory

(Home for Aberration-Corrected Electron Microscopes)

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High Temperature Materials Laboratory



## Introduction

- Oak Ridge National Laboratory will soon house three of the nation's first aberration-corrected electron microscopes, two that operate at intermediate voltage with sub-Ångstrom image resolution.
- These microscopes and other ultra-sensitive analytical instruments will require laboratories with highly stable environments in order to routinely achieve their ultimate performance.
- Such instruments are strongly influenced by magnetic fields (DC and AC), vibrations (floor, air turbulence, microphonics), barometric pressure changes, and both room and chilled water temperature fluctuations.

## Introduction

- By late 2003, ORNL will have constructed a new laboratory, designed to provide the proper environment for this advanced instrumentation, and other modern microscopes and related instruments.
- The **Advanced Materials Characterization Laboratory** will be constructed adjacent to ORNL's High Temperature Materials Laboratory. The aberration-corrected microscopes, and other sensitive microcharacterization instruments in the laboratory will support ORNL in-house research programs, and both the HTML and ShaRE national user programs.

## The Microscopes

## VG Microscopes HB603U 300kV Dedicated STEM

with aberration corrector from Nion Co.

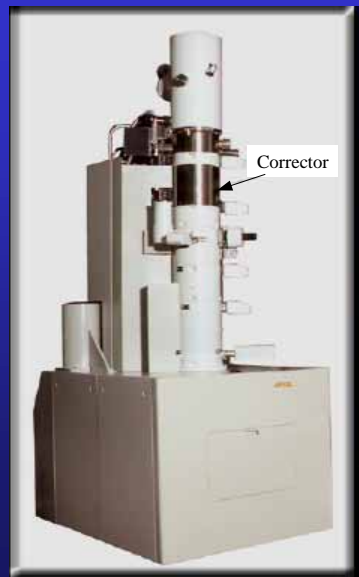


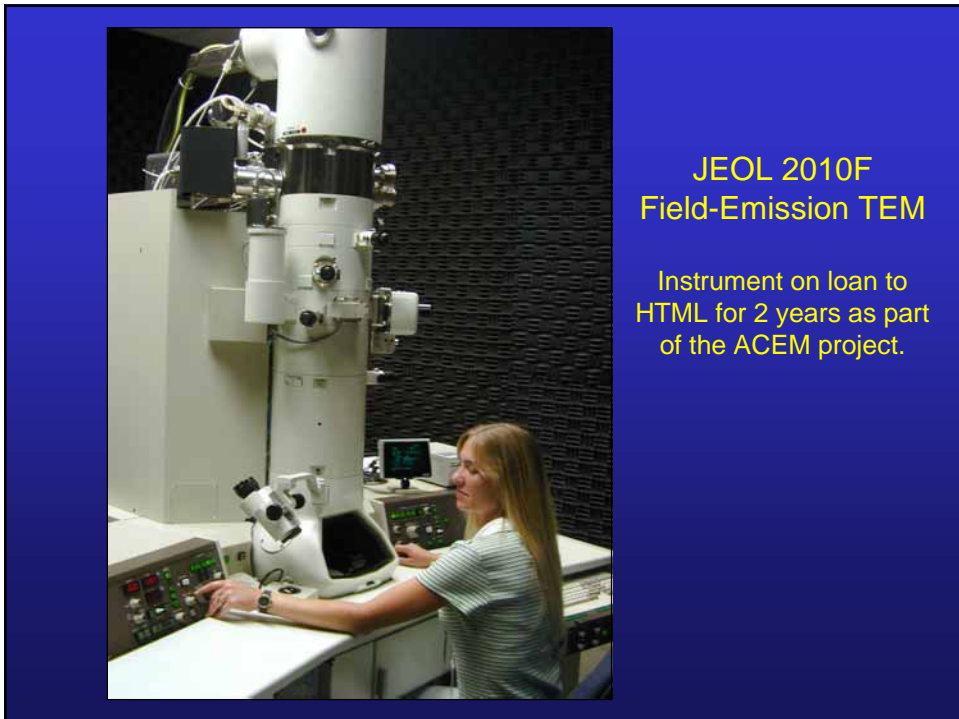
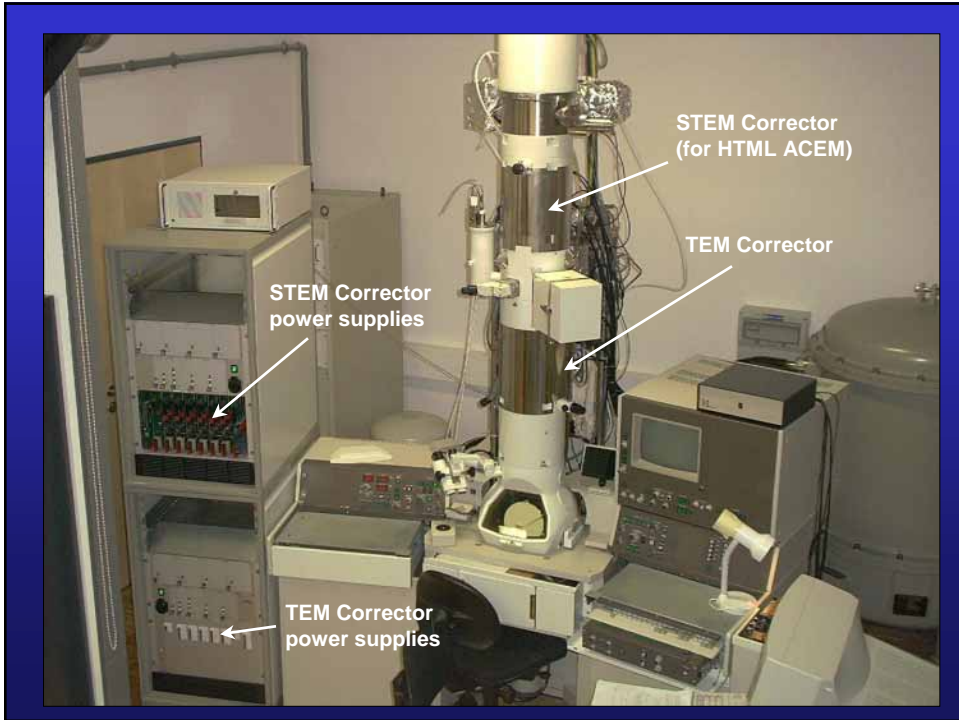
- STEM dark-field resolution 0.5Å (aim)  
(0.9Å achieved so far, limited by environment)
- Fully computer controlled

## JEOL 2100FEF-AC "ACEM" 200kV STEM/TEM

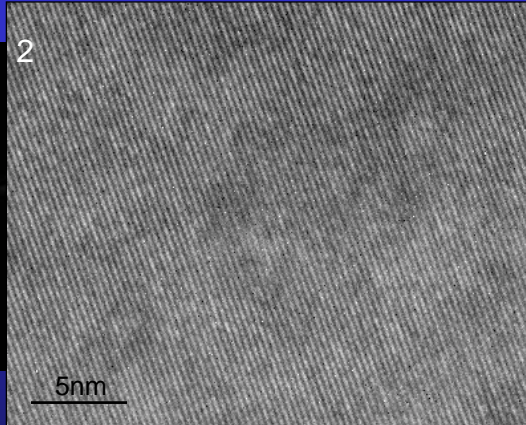
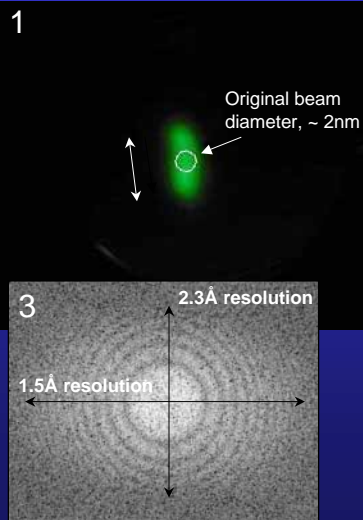
with aberration corrector for  
incident beam by CEOS Co. (Germany)

- STEM dark-field resolution 0.7Å
- TEM point resolution 1.9Å
- TEM bright-field information limit 1.2Å
- Remotely operated; stepper motor control of aperture drives
- No fluorescent screen
- 2k x 2k CCD camera for TEM imaging
- 1k x 1k wide-field CCD camera for general observation





## Effects of Magnetic Field Disturbances on the Performance of the JEOL 2010F TEM in Lab L115 in HTML, 11/07/2002



1) Focussed electron beam, showing sweep caused by 3mG mag field; 2) Image of silicon lattice, showing decrease of contrast of lattice planes perpendicular to field direction; 3) FFT of amorphous Si, showing difference in resolution in orthogonal directions due to field effect.

## The Triebenberg Laboratory

Prof. Hannes Lichte

Dresden University of Technology

### Requirements for HRTEM:

- **Specimen:** suitable for HRTEM
- **Microscope:** FEG, high-voltage,  $C_s$ -corrected
- **Microscopic Technique:** HRTEM, holographic methods, numerical image analysis and simulation
- **Environment:** mechanical vibrations, air-conditioning, acoustics, AC-stray-fields



Institute of Applied Physics, Dresden University of Technology

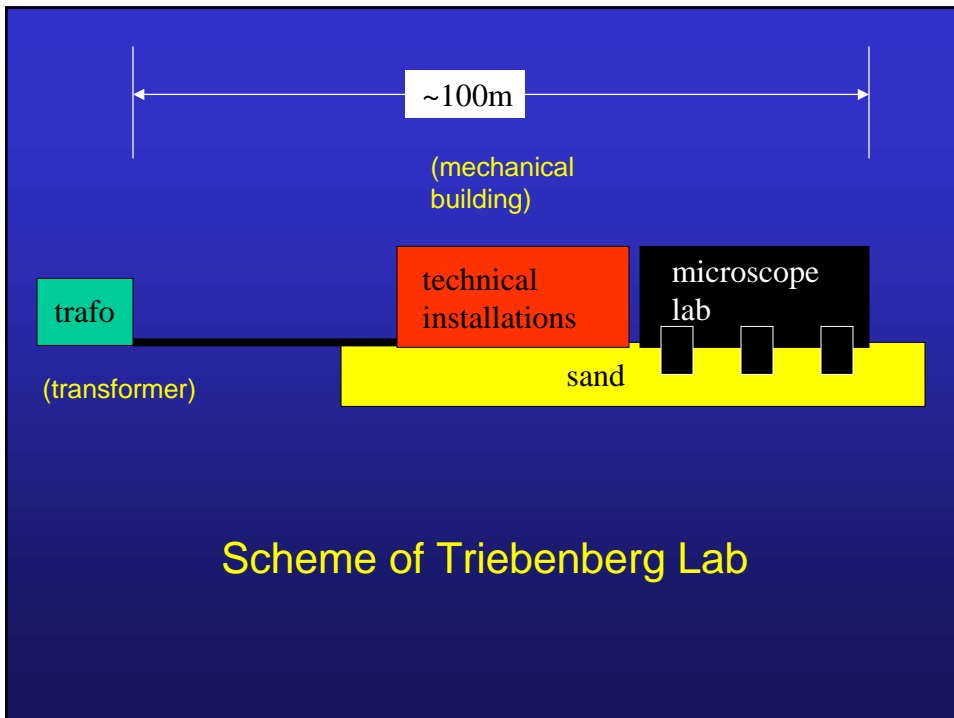
- no AC-stray fields
- no variation of local geomagnetic field
- no mechanical vibrations
- no acoustic noise

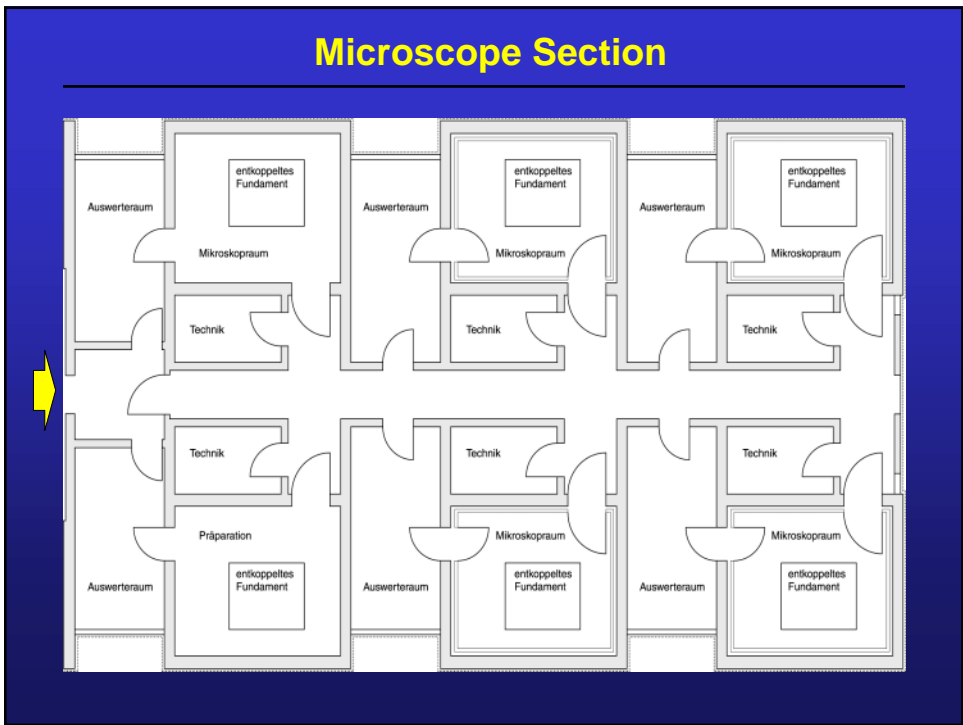
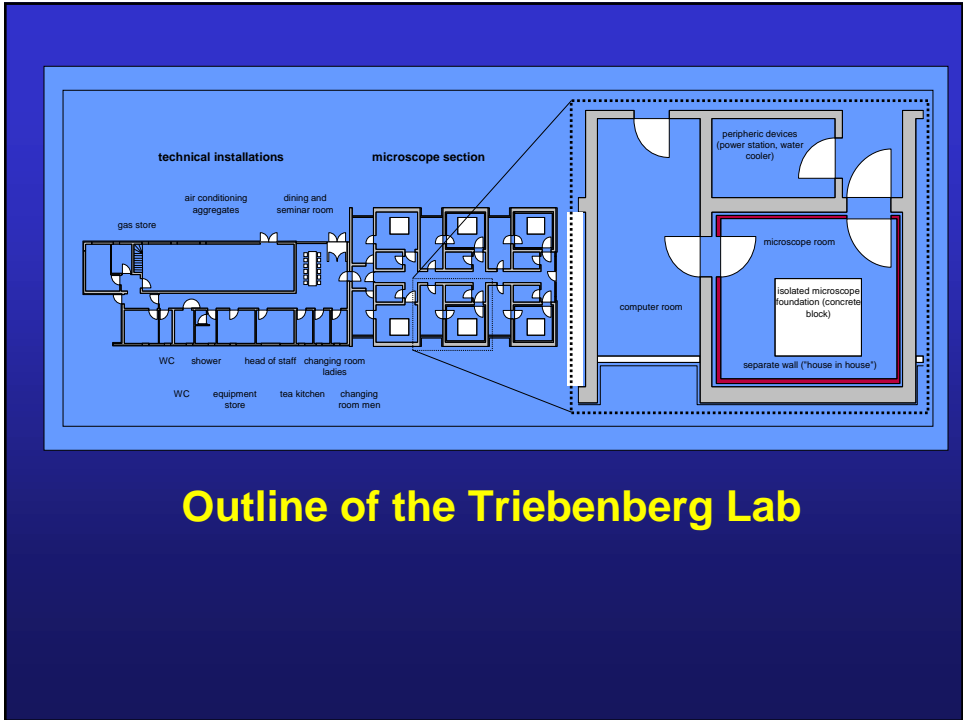


- no power cables
- no moving steel-vessels
- no cars or trains
- no airplanes
- no wind pressure on building



## Selection of Building Site for Laboratory





.....a highest-performing electron microscope is

☹ the most sensitive seismometer

therefore:

- distant from all outer sources of vibrations
- tree-belt as wind shield
- separation of the two buildings
- 4 separate levels of foundations: outer, inner, house-in-house
- microscope foundation (2 x 2.5 x 2 m deep)

## Foundation



## Foundation



(rubber sheet to insulate  
concrete from ground)



.....a highest-performing electron microscope  
is

⊗ the most sensitive AC-stray field meter

therefore:

- low stray fields main transformer
- no unneeded power lines in the microscope area
- no ground loops
- fiber-optic computer network
- remote switching
- sufficient spacing between neighbouring microscopes
- DC-illumination at the microscopes \*\*\*
- no gas-discharge lamps in the whole lab
- no computers at the microscope \*\*\*

the highest-performing electron microscope is:

☹ the most sensitive differential thermometer

therefore, Air Conditioning:

- $T = 22^{\circ}\text{C}$
- $\Delta T < 0.1^{\circ}\text{C/h}$
- whole microscope building at same temperature
- 4 machines running at same temperature

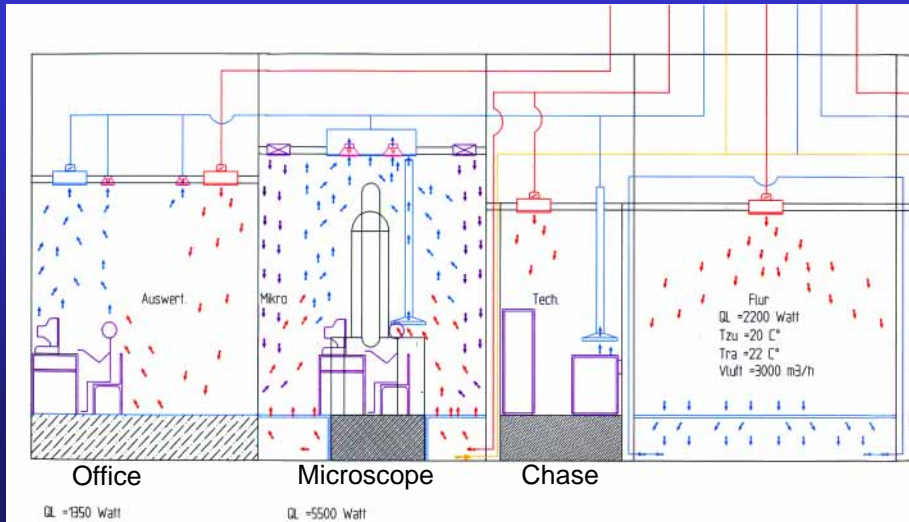
The highest-performing electron microscope is:

☹ the most sensitive microphone

therefore, Air Conditioning:

- low air speed
- additional water cooling
- intelligent air flow distribution around microscope
- switchable off for 5min (heat capacity)

## Air Conditioning



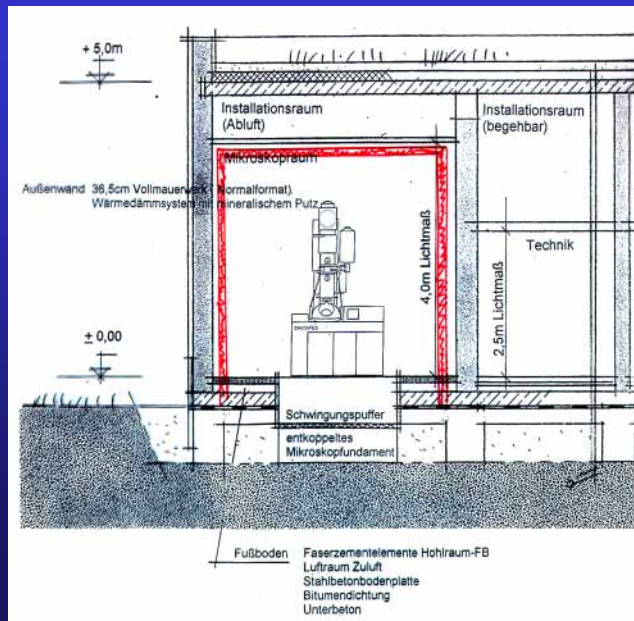
.....a highest-performing electron microscope is

⊗ the most sensitive microphone

therefore:

- extra technical cabinet (service chase) at each microscope
- 36cm thick interior walls throughout the microscope lab
- “house-in-house” acoustic shield around each microscope

## House-in-House



## The Triebenberg Laboratory



Courtesy of G. Schöler

## AMCL Design Characteristics

### Minimizing Vibrations:

- Concrete foundation slabs constructed over 3m thick "engineered fill"
- Heating, ventilation and air conditioning (HVAC) units located remote from instrument rooms
- Separate foundations for service building and instrument building
- Instrument water chillers installed in service building, remote from microscope rooms

## AMCL Design Characteristics

### Minimizing Magnetic Fields and Ground Loops:

- Foundation reinforcing steel will be epoxy coated to prevent electrically conductive paths
- PVC electrical conduits chosen to prevent ground current from passing through conduit and building structure \* \* \* \*
- Wireway provided in conduit system to allow measurement of spurious ground currents \* \* \* \*
- All power wiring (e.g. incandescent lights, wall circuits, instrument power) will be twisted to minimize fields \* \* \* \*

## AMCL Design Characteristics

### Minimizing Magnetic Fields and Ground Loops:

- Electrical power distribution center located as far from instrument rooms as possible
- Power outlets in instrument rooms localized to front and rear walls; additional power required for service will be by temporary extension outlets
- All computer communications to instruments and remote servers via fiber optic cable

## AMCL Design Characteristics

### Minimizing Magnetic Fields and Ground Loops:

- HVAC ductwork will be plastic \*\*\*\*
- Fire protection sprinkler system uses plastic plumbing
- Dielectric breaks in copper tubing used for compressed air lines
- Walls in instrument building are concrete masonry; no metal studs used
- Electrical grounding system configured in a single point grounding arrangement

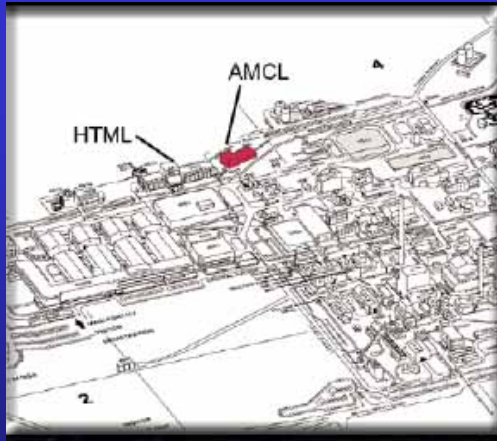
## AMCL Design Characteristics

### Minimizing Magnetic Fields and Ground Loops:

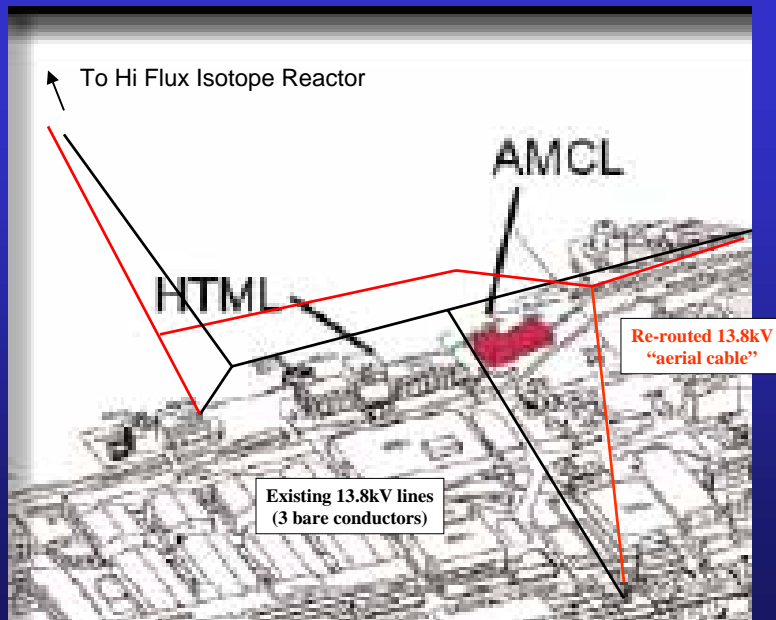
- Isolated ground system for instrument rooms
- Manual switch provided to transfer microscope from “clean” to “dirty” power during instrument bake-outs
- Motor -generator set to provide clean power

## LEED Score

Credit	Points	Points Possible
Innovation & Design	2	5
Sustainable Sites	9	14
Water Efficiency	3	5
Energy & Atmosphere	2	17
Materials & Resources	1	13
Indoor Environmental Quality	9	15
<b>TOTAL</b>	<b>26</b>	<b>69</b>



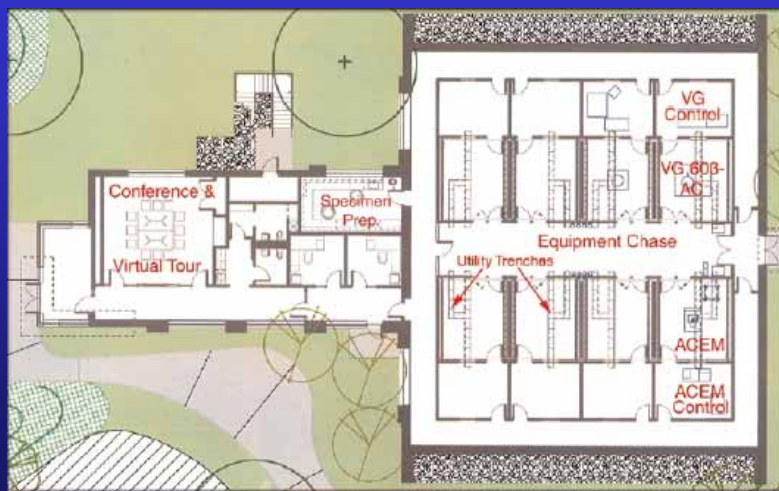
- The AMCL is located at the edge of the ORNL property, in a low-traffic area, adjacent to the High Temperature Materials Lab, which will supply clean power, steam and recirculated water



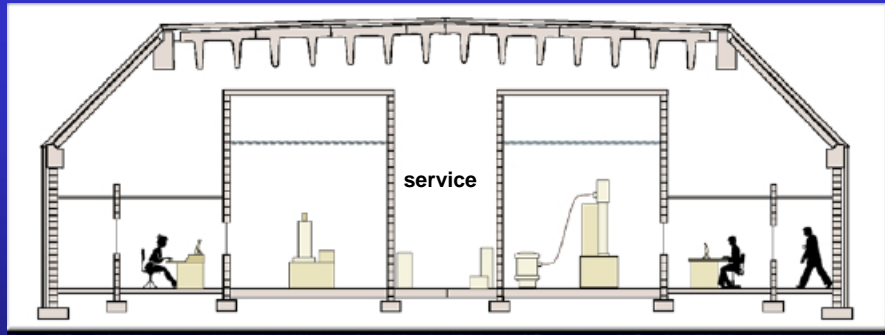


- The AMCL comprises 2 buildings: a two-story service building with HVAC equipment on the second floor, and a single-story instrument building, with high bays for instrument rooms.

## Building Plan

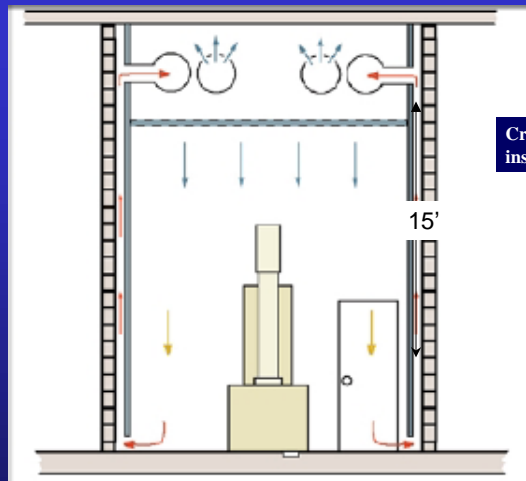


## Building Section



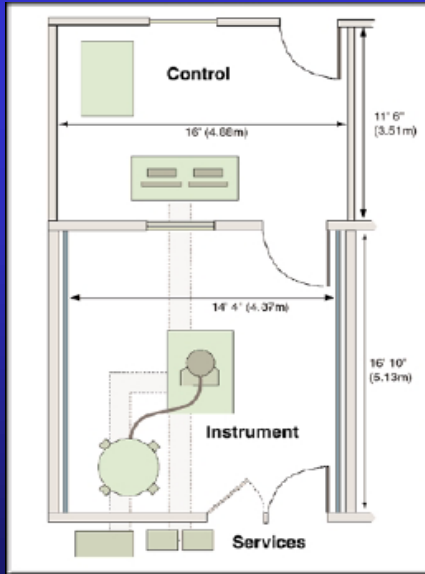
- Cross section through instrument building, showing "house-in-house" construction, with control rooms isolated from the instruments. Large service corridor provided to house pumps, power cabinets, etc.

## Instrument Rooms



Cross section through instrument room

- Plenum walls sound insulated
- Several air handling units for separate control of air flow and temperature in labs, control rooms and corridors



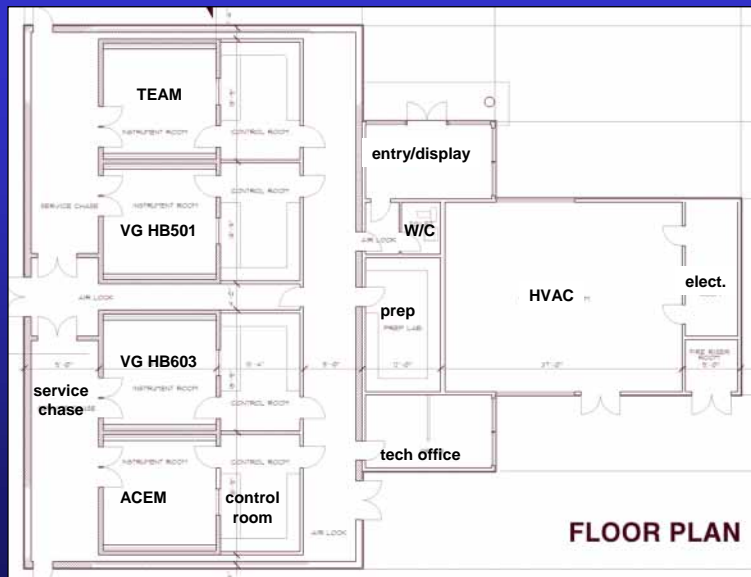
- Instrument room floor plan, showing floor trenches from service corridor for vacuum lines, power, pneumatic lines, and chilled water, and from the control room for power and computer control connections

## Aim Design Parameters for AMCL:

- Magnetic stray fields, ambient:  
<math><0.05\text{mG}</math> at 60Hz
- Floor Vibrations:  
<math><2\text{nm p-p}</math> on any axis at <math><30\text{Hz}</math> \*\*\*\*
- Air Flow:  
<math><5\text{cm/sec}</math> across the column
- Temperature Stability:  
<math>\pm 0.2</math> degrees Celsius/hr or less



AMCL "4 Lab" Floor Plan



## Acknowledgements:



Planning and construction funds provided by the department of Energy, Office of Science, Landlord General Plant Project funds for Oak Ridge National Laboratory, operated by UT-Battelle, LLC.

**Architect:** Lord, Aeck & Sargent, Atlanta, GA

**Mechanical:** Newcomb&Boyd, Atlanta, GA

**Structural:** Stanley D. Lindsay & Associates, Nashville, TN

**Civil:** Barge Waggoner Summer & Cannon, Oak Ridge, TN

**Commissioning:** Working Buildings, Atlanta, GA

**Construction start: Monday, Jan. 20!**

AMCL "ConstructionCam" at:

[www.ms.ornl.gov/htmlhome](http://www.ms.ornl.gov/htmlhome)

## New Building to be Built in West Parking Lot Designed to Minimize Problems

- ORNL put up 4.8M\$ to design/build special building
- Architect-engineering firm designed 6- or 8-lab bldg.
- Responses to RFQ were much too high; needed to rescope to smaller building
- Now working on new process (GMPC) to get 4-lab building at reduced price

The highest-performing electron microscope is:

- ☺ built with extraordinary care to resolve atoms
- ☹ the most sensitive AC-stray field meter
- ☹ the most sensitive seismometer
- ☹ the most sensitive microphone
- ☹ the most sensitive differential thermometer
- ☹ the most sensitive dust detector

## Meanwhile, ACEM is Under Construction

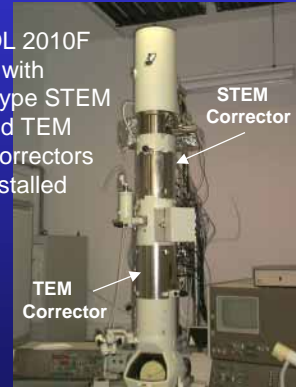
- Still on schedule to be delivered August 2003: we have asked about what they want to do re: late building



JEOL 2100FEF-AC  
"ACEM"

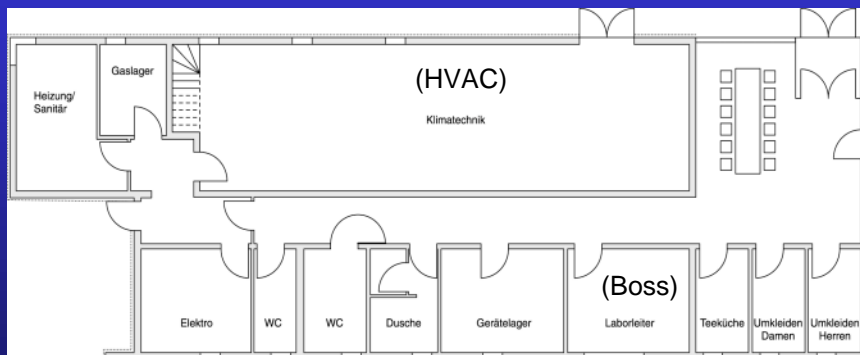
Rendering showing  
approximate appearance  
of STEM probe corrector.

JEOL 2010F  
with  
Prototype STEM  
and TEM  
Cs Correctors  
installed

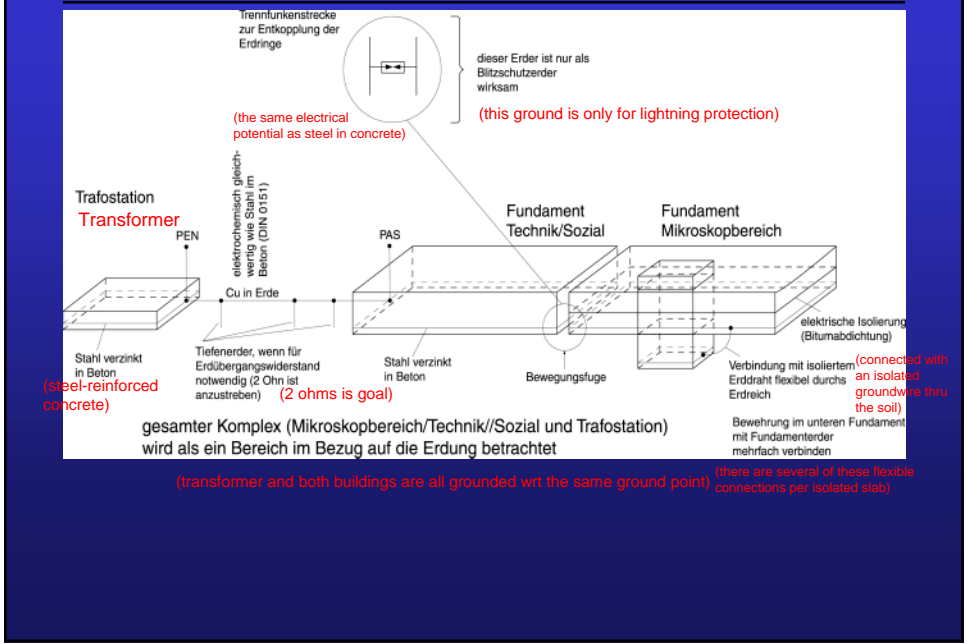


CEOS Co., Heidelberg

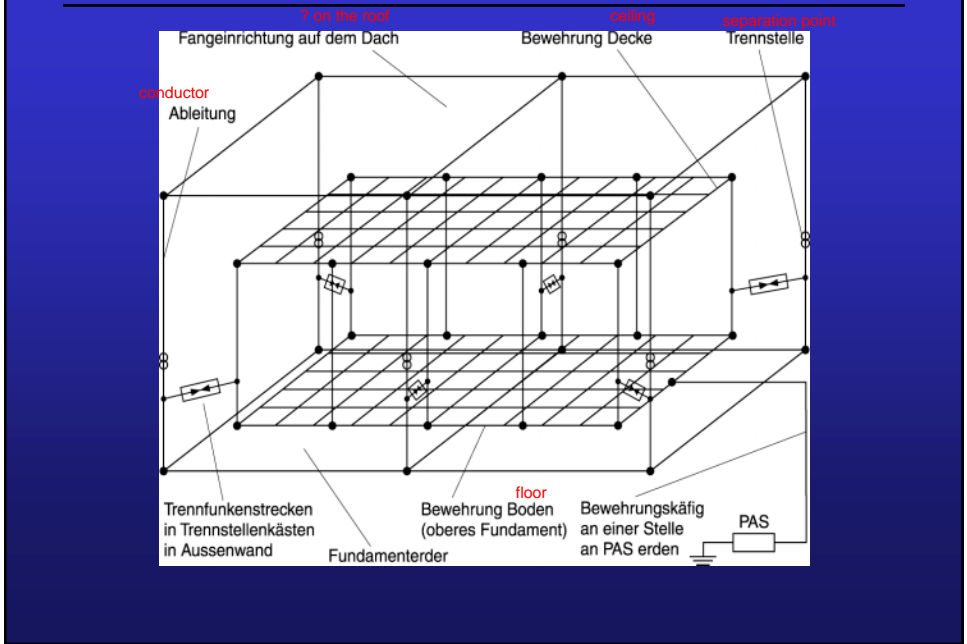
## Service & Social Section



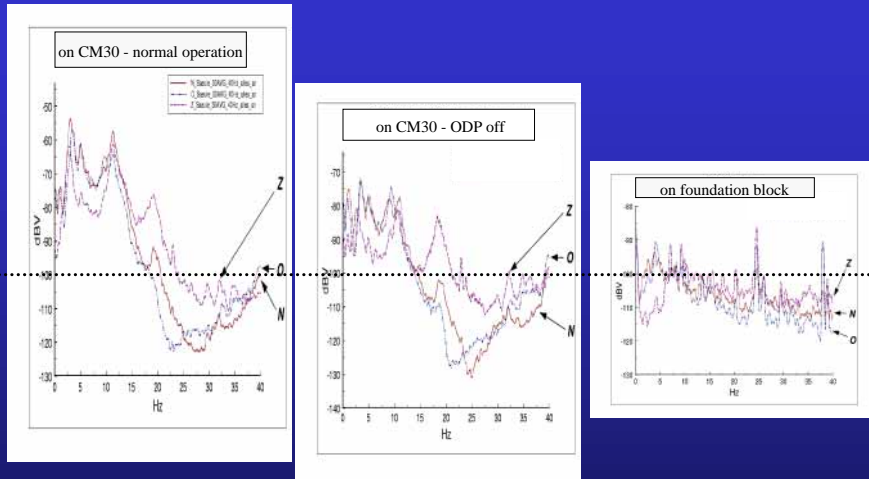
# Potential Equalization of the Lab



# Potential Equalization of the Lab



## CM30FEG/UT-Special Tuebingen



vibration measurements in the Tuebingen-lab by Günter Lang

## LEED Approach

- Commissioning Approach
  - During Design
  - During Construction
- Low Volume Air Systems
- Utilizes Central Plant at HTML
- Close Attention to Power Issues

## LEED Approach

- Sustainability Approach
  - Team Approach with Strong Owner Involvement
  - ORNL LEED Officer involved from start
  - High Recycled Content
  - Site Reclamation
  - Extensive Commissioning effort

## Site Issues

- Companion to the HTML
- Vibration Issues
- EMI/RFI Issues
- Site Reclamation Approach
- Site Utilities

# **Building Design Issues**