The University of Melbourne

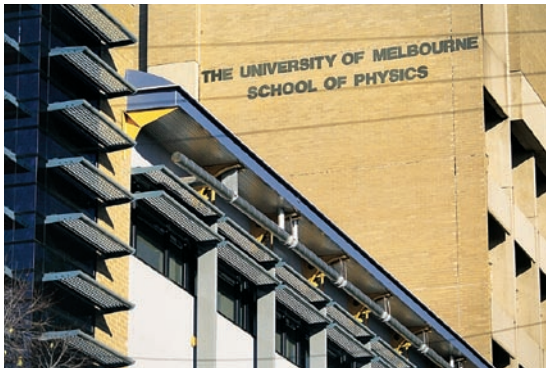

FIGURE 1

The School of Physics (David Caro) Building.

FIGURE 2

The Device Modelling (Theory) Group are located at the Melbourne Node and are involved in device design, operation and new algorithms development for the Centre.

The Melbourne Node of the Centre is situated in the David Caro and Nuclear Physics Buildings of the University of Melbourne (Figure 1). It is co-located with the Microanalytical Research Centre (MARC), Nanostructural Analysis Network Organisation (NANO-MNRF), Quantum Communications Victoria (QCV) and the new Melbourne Institute of Materials. The Centre is one of the largest research groups in the School of Physics and is home to: cleanrooms, the Pelletron accelerator, Advanced Materials Laboratory, Scanning Probe Microscopy resources (SPM) and the Theory and Modelling Group (Figure 2).

Laboratory based research staff and students are based in offices located on levels 2, 4 and 6 of the building and the combined office space totals 375 m^2. The MARC office, which is home to the Node Administrator, provides centralised resources for the group. In 2008, the Melbourne node experienced a number of staff changes including that of the Node Director and the retirement of a senior laboratory engineer (Mr. R. Short).

Centre for Quantum Computer Technology Cleanroom (CQCTC)

Completed in October 2002, the Centre's Cleanrooms span more than 200 m^2 and comprise the following functional areas: a dual Class (350/3500) changeroom (23 m^2), services (32 m^2), wet chemical processing (40 m^2), Scanning Electron Microscopy (SEM)/Focused Ion Beam (FIB) (19 m^2), general measurement (41 m^2), Advanced Spectroscopy (27 m^2) and Scanning Probe Microscopy (23 m^2). The cleanroom is equipped with two turbulently ventilated (HEPA) fumecupboards, chemical storage and a decontamination station. It is serviced by filtered (HEPA) and conditioned air, chilled water, gas exhaust, high purity gas supplies, instrument grade air and vacuum. Many of these services are configured for remote (and wireless) operation. The following instrumentation operates within the Cleanroom environment: a Colutron low energy ion implanter, a JEOL/Orsay Physics Focussed Ion Beam (FIB) column integrated (crossed beam) with a Scanning Electron Microscope (SEM) and Elphy Quantum Lithography control system, a Speedline Coating Systems P6708 Spin Coater, JEOL JAFM 4500XT UHV Atomic Force Microscope with STAIB Surface Spectroscopy facility and a Renishaw confocal micro-Raman spectrometer with operating laser wavelengths of 244 nm, 325 nm and 514.5 nm.

The adjacent Transmission Electron Microscope (TEM) laboratory (40 m^2) was vacated this year (July 2008) with the instrument relocated to Deakin University (Geelong). In 2009/2010, this laboratory will be reconfigured to perform quantum measurements of the Si:P system using a new dilution fridge facility (see the Melbourne Quantum Measurement report).

Ion Accelerator Facilities

The Melbourne Node is home to three accelerators. The largest of these, the NEC 5U Pelletron, operates in the Pelletron Laboratory which is located in the basement of the Nuclear Building. It was originally commissioned in 1975 and is a high brightness source of light ions operating at charging potentials from 0.5 to 5MeV. It is routinely used to perform: Ion Implantation, Rutherford Backscattering (RBS), Proton Induced X-ray emission (PIXE), Ion Beam Induced Charge (IBIC) and Channelling Contrast Microscopy (CCM) on a variety of materials. It is now home to the CSIRO microprobe beamline which was originally operated at the North Ryde facility prior to 2006. During 2008, the Pelletron laboratory has undergone substantial change with the relocation of the MP2 beamline. In addition, this area has undergone a consolidation of research space with 100 m^2 being re-allocated to other research activities. The Pelletron laboratory comprises ~400 m^2 of floor space spanning 3 levels.

The second accelerator is an Orsay Physics Focussed Ion Beam (FIB) with crossed beam SEM. It is fitted with gas injection and eutectic sources and the system is able to process (i.e. machine) materials with sub 100 nm resolution. This instrument was assessed for conversion into a precision, multi-source, ion implanter for quantum device development. Preliminary results using a nickel source to produce centres in diamond have been successfully obtained in 2008 with further work planned for 2009.

The third accelerator is a Colutron (Figure 3) low energy ion implanter (0.01–15keV) predominantly used for phosphorus implantation of quantum devices. It was originally commissioned in 2001 and is equipped with a: G2 ion gun, beam imaging system, computer controlled ion selection, beam on demand and single ion detection capabilities. In 2005, the system was upgraded to provide computer controlled, ion beam scanning allowing large area implantation.

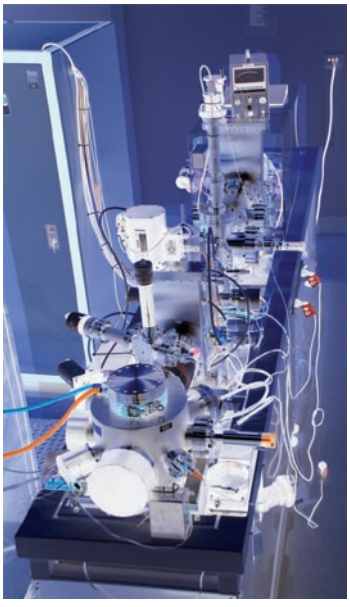

FIGURE 3

The Colutron low energy ion implanter which is used for precision (single) ion implantation of Si:P quantum devices.

Materials Fabrication Facilities

Fabrication and deposition facilities are located in the Advanced Materials, Pelletron and Cleanroom laboratories. General facilities in the Pelletron and Advanced Materials Laboratories include: wet chemical processing, inert gas furnace annealing, sample polishing, time-resolved reflectivity and optical microscopy. The Advanced Materials Laboratory (70 m^2), located in the basement of the Physics building, houses an Astex microwave HPMD/ECR system suited to diamond and diamond like material coatings. This system experienced catastrophic failure as a result of a central cooling system failure. The damage has been assessed by the insurer and replacement options are currently under consideration.

The Pulsed Laser Deposition (PLD) laboratory (70 m^2), located on the fourth level of the building, is equipped with a Class 350 Cleanroom (10 m^2), Class 35 laminar flow cabinet, turbulently ventilated fumecupboard and a Type II deionised water purification system. The Pulsed Laser Deposition system is being relocated during 2008/2009 to the Engineering Faculty at the University of Melbourne where it will become part of the fabrication infrastructure for the new Melbourne Institute of Materials.

Micro- and nano-fabrication facilities at the Melbourne Node are located in the CQCT cleanroom and consist of an electron beam (EBL) and photolithographic processing facility. A UV front side mask aligner (Neutronix Quintel Q4000-6 UV) was funded by the ARC (2006) and the instrument was fully commissioned in March 2007. Its functionality includes: a flexible size vacuum chuck system for handling wafers (6") and fragments, sub-micron feature resolution, contact/non-contact/vacuum/proximity exposure modalities and the ability to process both thin and thick photoresists. The EBL facility is associated with the SEM/FIB which includes a Wraith pattern generator. In 2008, a lithography companion technology was tendered for and commissioned in the CQCT cleanroom. It comprised a custom Thermionics physical vapour deposition system (Figure 4) with both electron beam and resistive filament sources and a quartz crystal monitor for thickness control.

FIGURE 4

The new (2008) Thermionics VE180 custom physical vapour deposition system commissioned in the cleanroom at the Melbourne Node.

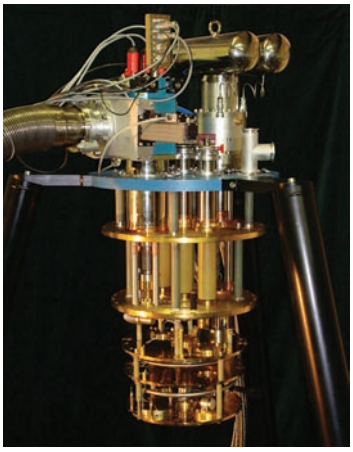

FIGURE 5

Photograph of the new Leiden Cryogenics milli-Kelvin cryostat insert. This system is scheduled to be commissioned at the Melbourne Node in 2009/2010.

Device Measurement Facilities

Electrical characterisation takes place in the Pelletron and undergraduate teaching laboratories where 4 point probe, low noise DC SQUID (Star Cryo-electronics) and Deep Level Transient Spectroscopy (SULA) instruments operate. In 2007, a new 77K Hall Effect system was acquired using University and Centre funding. This instrument was fully commissioned in 2008 and will be used for research and teaching. In addition a milli-Kelvin, adiabatic magnetisation refrigerator (Figure 5) was ordered in 2008 (to be delivered in 2010) using funding from an ARC LEIF grant. The successful vender (Leiden Cryogenics) will supply the cryogen free measurement platform (see the Melbourne Quantum Measurement report) which uses pulse tube refrigeration technology combined with a traditional dilution unit enabling the fridge to reach a base temperature of $<$15mK, with a cooling power of 450μW at 120mK. It will be supplied with a superconducting 3D vector magnet allowing the application of fields up to 9 T in one direction, and 1 T in each of the remaining orthogonal directions. Optical access is facilitated through the use of cryostat windows along with optical fibre feedthroughs. This system will be a fundamental tool for the electrical-optical characterisation of Si:P related samples in a low temperature, high magnetic field environment.

Advanced Spectroscopy Facilities

The Melbourne Node is home to three commercial micro-Raman Spectrometers for conducting Ultra-Violet, Visible and Near Infra-Red Raman and Luminescence studies. The systems are located in the Pelletron (30 m^2) Laboratory (Dilor XY), the CQCT Cleanroom (Renishaw RM 1000) and the Bio21 Molecular Science and Biotechnology Institute (Renishaw Invia Reflex). The Dilor system is a triple grating, high resolution spectrometer with a new (2008) diode pumped, frequency doubled solid state excitation source. The Renishaw RM1000 system is a single grating, extended wavelength Raman/luminescence spectrometer (244–1000 nm) with Coherent I90 FRED, Kimmon HeCd and Stellar Pro Modulaser excitation sources. The Renishaw Invia Reflex system (Figure 6) is configured with both visible and near infrared excitation sources and was fully commissioned in 2008.

FIGURE 6

The new InVia dual excitation wavelength, micro-Raman spectrometer located in the BIO21 research precinct of the University of Melbourne.

Atomic Imaging Facilities

This Node is home to a range of scanning probe instruments (AFM) which include a JEOL JAFM 4500XT UHV AFM which is capable of CITS, lateral force, scanning Kelvin and modulation imaging modes with atomic resolution. It also features: an argon ion gun, e-beam evaporator, cleaver and atomic hydrogen source. A Staib Surface Spectroscopy facility was added to this system in 2002 and includes: a micro-focus electron gun with scintillation detector for SEM imaging, cylindrical mirror analyser (CMA) with integral electron gun for Auger spectroscopy and SAM and an X-ray source for XPS analysis.

A second JEOL AFM (JSTM 4200A) is located in a renovated laboratory (completed in 2004) and this system is equipped with many of the same features as the 4500 XT. The two JEOL systems are complimented by a Nanonics NSOM/AFM and an NT-MDT SMENA portable AFM (located in the undergraduate teaching laboratories). The Nanonics system provides 50 nm lateral imaging resolution and has been successfully interfaced to the Renishaw micro-Raman spectrometer. The NT-MDT SMENA AFM is located in the School's undergraduate teaching laboratories where it caters for both undergraduate teaching and research activities.