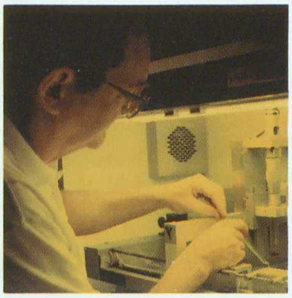
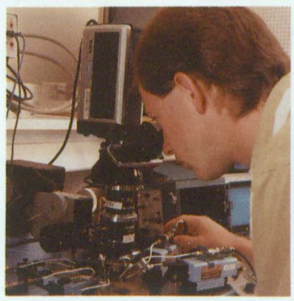
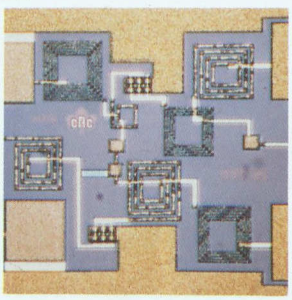
THE DEPARTMENT OF
COMMUNICATIONS
RESEARCH
PROGRAM

LE PROGRAMME
DE RECHERCHE
DU MINISTÈRE
DES COMMUNICATIONS

COMMUNICATIONS DEVICES AND COMPONENTS RESEARCH







Communications
Canada

The Communications Devices and Components Research Laboratories are located at the Communications Research Centre, five kilometres west of Ottawa, at Shirleys Bay

3701 Carling Avenue,
P.O. Box 11490,
Station H,
Ottawa, Ontario
K2H 8S2
Telephone: (613) 998-2351
Fax: (613) 990-7988.

Photos courtesy of Creative Visual Services, Communications Research Centre.

Cat. No. C022-88/1989
ISBN 0-662-57155-X

Canada

THE DEPARTMENT OF COMMUNICATIONS RESEARCH PROGRAM

LE PROGRAMME DE RECHERCHE DU MINISTÈRE DES COMMUNICATIONS

COMMUNICATIONS DEVICES AND COMPONENTS RESEARCH

The Communications Devices and Components Research (DCR) Branch investigates the generic electronic technologies used to process and manipulate communications signals and information technology systems. It carries out research into electronic devices, components and circuits, optical communications, and photonics. Much of this work is undertaken to support the communications, radar electronics and information technology needs of other federal departments and agencies. Often the research is carried out through partnerships with private firms or with university research groups.

THE FOCUS

Communications research organizations need leading-edge competence in microelectronics – the miniaturization of electronic subsystems which are shrunk onto small chips. For the most part, DCR is investigating technologies based almost entirely on compound semiconductor materials like gallium arsenide (GaAs). Gallium arsenide complements silicon technology and will offer a wealth of attractive business opportunities during the next decade.

DCR groups its research activities around nine themes:

- monolithic microwave integrated circuits (MMICs),
- very high-speed digital integrated circuits,
- phased-array antennas,
- EHF components,
- optoelectronics,
- new compound semiconductor devices,
- optical communications,
- photonics, and
- reliability studies.

Because it has properties that make it eminently suitable for microwave and for optical circuits, gallium arsenide figures in most of these fields of research. In fact, over three-quarters of DCR's research personnel and funding is devoted to this new and demanding technology.

The Hermes satellite designed and built at CRC. The satellite contains a GaAs field effect transistor amplifier built by DCR which was the first GaAs device to fly in space.

RESEARCH ACTIVITIES

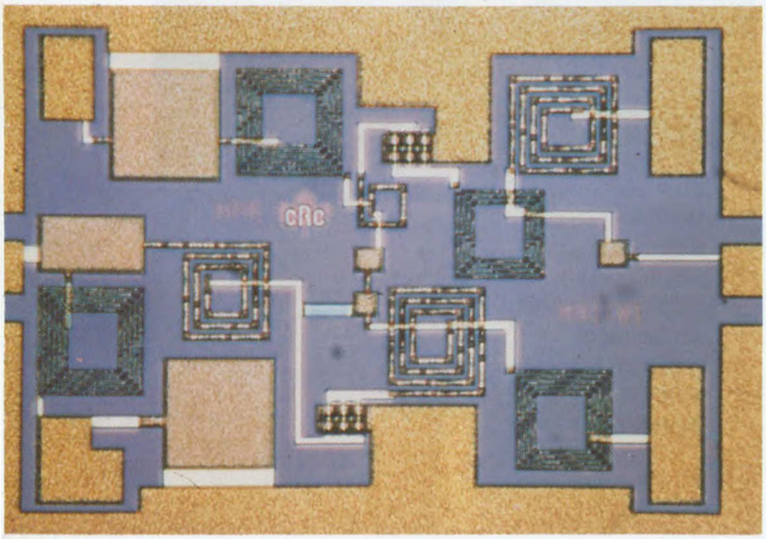
1. Monolithic Microwave Integrated Circuits

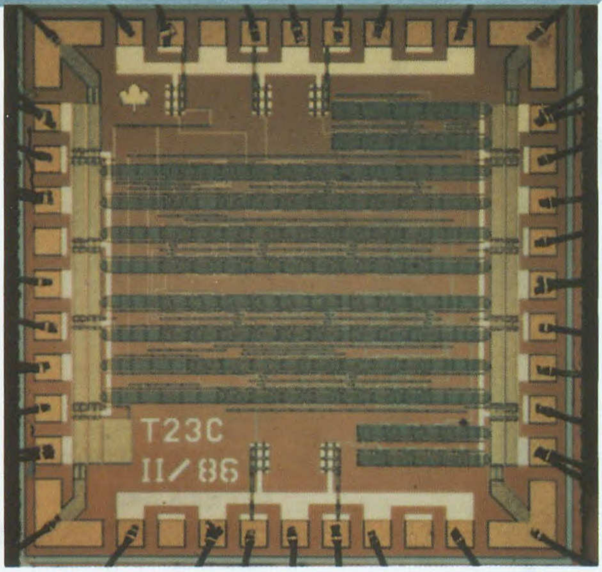
One significant application for gallium arsenide technology is in creating monolithic microwave integrated circuits (MMICs) – microwave systems on a gallium arsenide chip. Gallium arsenide technology promises significant advantages in terms of size, weight, reliability, cost and performance. These advantages will be of particular benefit in

- mobile receivers and transmitters for personal communications applications;
- elements of active phased-array antennas;
- microwave repeaters for long-distance telephone service;
- satellite transponders used in communications;
- earth terminal components for satellite-to-home TV;
- optical communications; and
- radar.

In fact, some applications (like active phased-array antennas) are only now becoming practical as a result of the emergence of MMICs. And it may soon be possible to build subsystems that feature microwave analog functions integrated with digital functions on the same chip.

Photomicrograph of a GaAs MMIC.





At present, DCR's research in GaAs MMICs is concentrated on techniques for the design, modelling, fabrication and testing in the ultra-high to millimeter wave frequencies; the use of foundries; and the demonstration of working chips in prototype communications hardware.

2. Very High-Speed Digital Integrated Circuit Components

In the field of digital circuitry, the laboratory is working in two areas: silicon VLSI circuits and gallium arsenide integrated circuits.

In its only research in silicon technology, DCR is developing a variety of high-speed and very large-scale integrated (VLSI) circuits, now becoming available for both military and civilian systems. High-speed VLSI promises substantially faster processing and routing of

Photomicrograph of a GaAs digital integrated circuit.

complex signals, and makes possible new spectrum utilization techniques.

Using compound semiconductors like gallium arsenide in digital circuits can yield components with even higher switching speeds. Such circuits can be particularly useful in large systems, where incoming data must be sorted and routed quickly before being processed further. In certain cases, GaAs digital circuits are preferable to silicon-based circuits because the higher speeds attainable with gallium arsenide can reduce the number of chips a system uses. That, in turn, reduces the associated power requirements and thermal problems.

These technologies – alone or in combination – will be useful in

- bandwidth reduction and sharing techniques for systems – like HDTV – that have a high data throughput;
- creating fast-hopping frequency synthesizers with lower noise and higher frequency, for greater privacy and jamming resistance when using the airwaves;
- block demodulators and switching systems for signal processors on board satellites;
- low-cost synthesizers for mobile and portable terminals;
- high-speed multiplexers and wideband digital filters for land communications (for more efficient high-speed data transmission);
- phased-array antenna controllers; and
- optical modulation controllers.

DCR's current interest is the design and testing of complex silicon integrated circuits for signal processors on board satellites, and GaAs digital integrated circuits for very high-speed prototype subsystems and special applications like analog to digital conversion.

3. Phased-Array Antenna Technology

Over the past 20 years, antennas – particularly for communications satellites – have become highly sophisticated. Most commonly, they are offset parabolic reflectors, and the shape of their beams is generated using feed arrays of varying complexity.

Thanks to GaAs MMICs, it is now possible to consider active phased-array antennas capable of very complex beam patterns that can be electronically pointed and shaped, without the need for a reflector, and that offer sidelobe and null steering capabilities. These benefits, together with greater reliability and "fail-soft" features, will permit frequency reuse; this in turn will influence future spectrum utilization. These advances offer potential solutions to many of the antenna requirements for mobile land, sea and air communications systems. And active phased-array antennas are under consideration for military radars and airport microwave landing systems, where they will make takeoff and landing more accurate and safer.

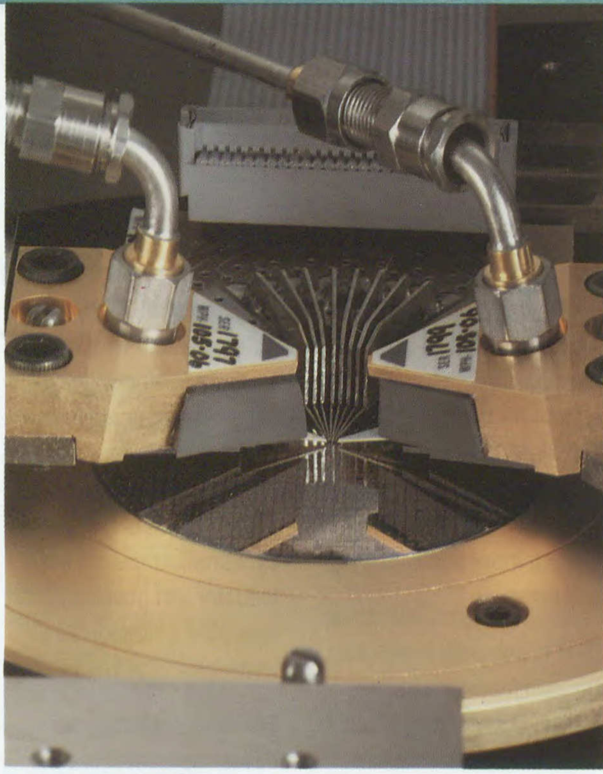
DCR is currently looking at the development of planar arrays incorporating MMICs and at integrated satellite receive antennas that feature MMIC and antenna elements incorporated onto the same GaAs substrate. These antennas-on-a-substrate have a future in personal communications via satellite.

4. Extremely High Frequency (EHF) Components

Future satellite communications systems will exploit the EHF bands (20, 30 and 44 GHz). In fact, such systems are under development in the US, Japan and Europe, where they will transmit business data between metropolitan areas and make military communications largely immune to jamming. There are significant implications for both industry and government in spectrum utilization and civil signal distribution.

EHF is also mooted for delivering rural subscriber communications systems, HDTV broadcasting, high-rate business data transmission and communications within buildings. Military applications will benefit where suitable frequency choice and rapid fall-off in signal strength are desirable for secure communications over a local area. Personal and portable mobile communications terminals for EHF may also become practical. All of these developments rely on GaAs technology.

Testing phased-array antenna components in an anechoic chamber.



The use of EHF bands for civil communications in Canada is not likely until after the mid-1990s. However EHF has been approved for military use and for foreign systems, and development is well under way in other countries. If Canadian industry is to respond to emerging procurement needs, the technical competence must be developed now. Chief among the present needs is an ability to manufacture subsystem components in order to avoid dependence on foreign suppliers and maximize Canadian content.

High frequency probing of microwave circuits before dicing the wafer.

Present DCR research focuses on the design, fabrication and testing of miniature hybrid microwave integrated circuits (MHMICs) for EHF transceivers and on advanced devices that will improve performance at these higher frequencies.

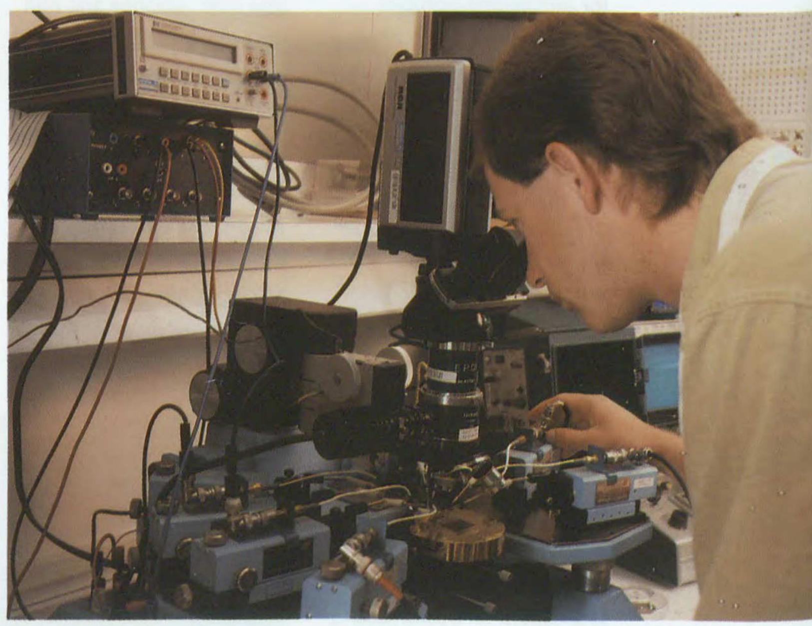
5. Optoelectronics

Optical communications offers a low loss rate, broad bandwidth, potential reduction in the weight of the systems, and immunity to electromagnetic interference and eavesdropping, to mention only a few of its advantages. The role of optical communications in Canadian telecommunications networks will therefore expand, although commercialization is still in its early stages. Until now, optical signals have been distributed within and between optoelectronic chips using fragile, bulky and unreliable fibre connections.

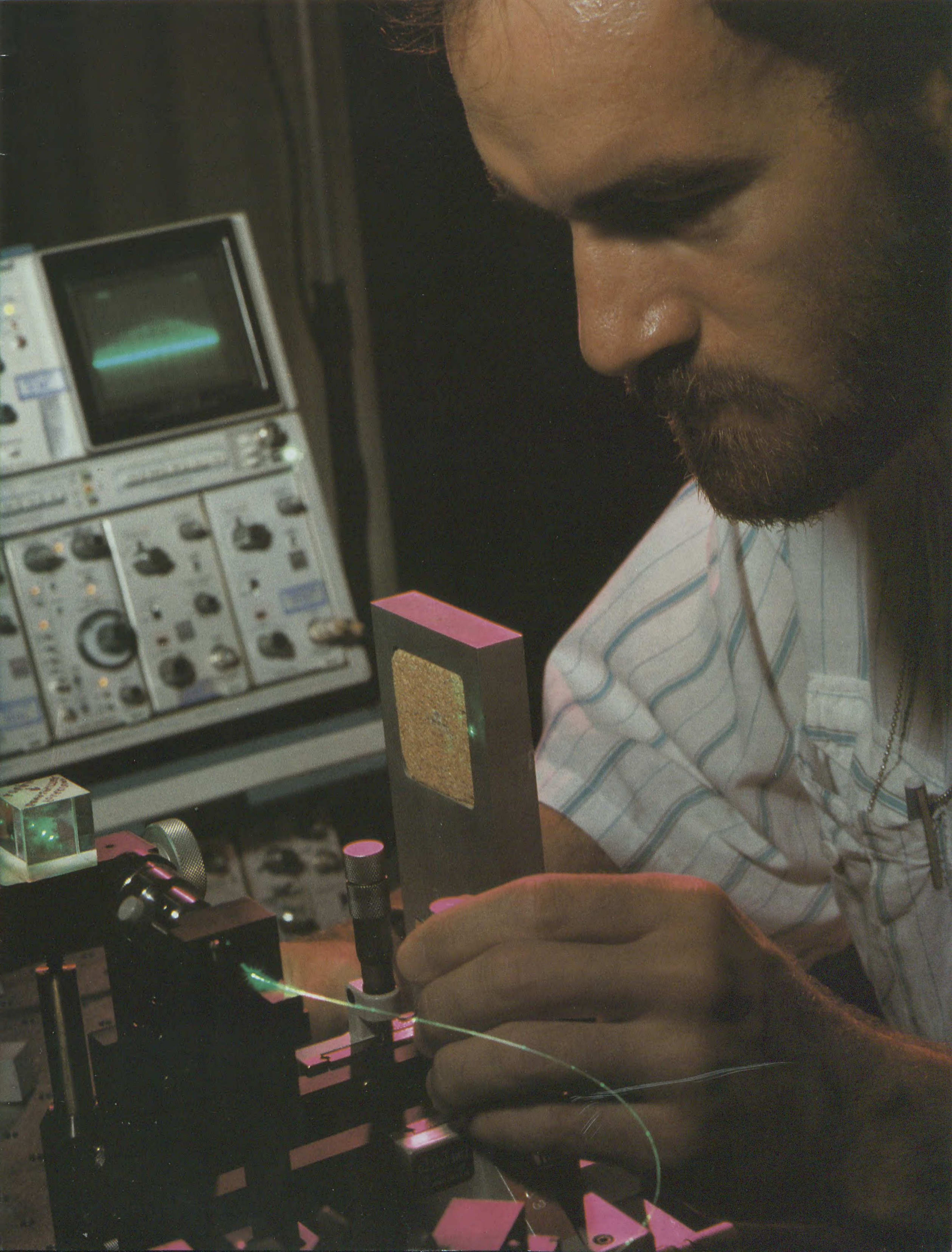
DCR's research has produced a firm basis for developing advanced hybrid optoelectronic circuits. Current work is directed toward achieving optimum speed and performance in the individual components, and in developing circuits and systems rugged and reliable enough for commercial and military use.

DCR is doing this by growing and characterizing alternative semiconductor materials, such as gallium-indium arsenide (GaInAs) and indium phosphide (InP), and by designing and fabricating new optoelectronic devices and optical waveguide structures that will permit optoelectronic components to be integrated with present microwave and high-speed digital technologies. Devices and components that convert optical data to electronic

Electronically testing and characterizing advanced device structures.



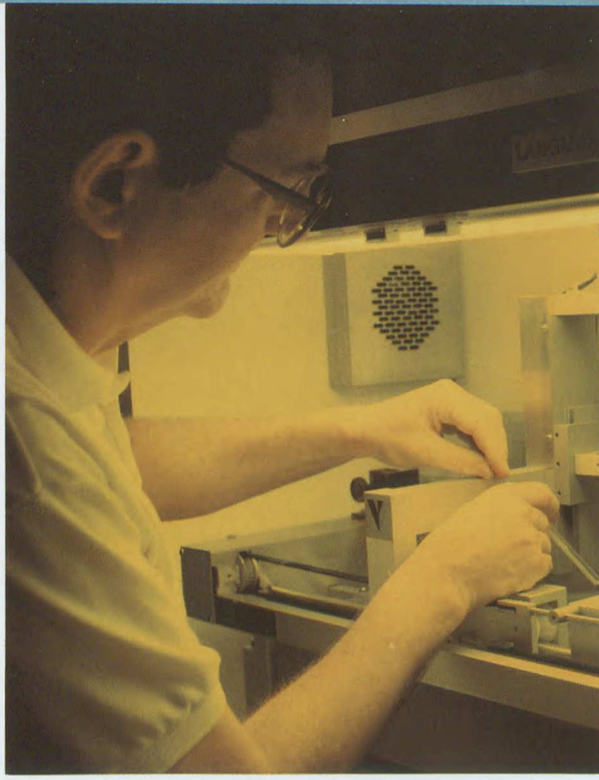
Non-linear studies on optical fibres.



data and back again "on-chip" will be used in high-speed signal processing applications such as computer-to-computer interfacing, state-of-the-art phased-array antennas, HDTV systems and satellite communications.

6. New Compound Semiconductor Devices

Gallium arsenide is the simplest of the compound semiconductors and the basic building block of DCR's research program. Almost all of the integrated circuits presently being developed concentrate on gallium arsenide substrates. They usually incorporate a homogeneous deposited active layer or an ion implanted area upon which the devices – usually field-effect transistors – are built. While the potential in these techniques has not yet been fully exploited, the operational limits in terms of bandwidth, speed, frequency and noise are already known. It is important that R&D focus on easing the entry of these techniques into the sphere of applications.



Deposition of organic thin films used in photonic device fabrication.

Variations on GaAs, adding other elements, can offer superior performance characteristics like lower noise or higher switching speeds. By using an advanced active layer deposition system, DCR can influence the materials studied and evaluate their suitability for advanced applications. One of the variations on GaAs is gallium aluminum arsenide, which forms the basis for advanced devices like the heterojunction bipolar transistor (HBT) and quantum-well structures. Indium phosphide (InP) is a simple but demanding compound semiconductor that the laboratory plans to investigate for fabricating laser diodes.

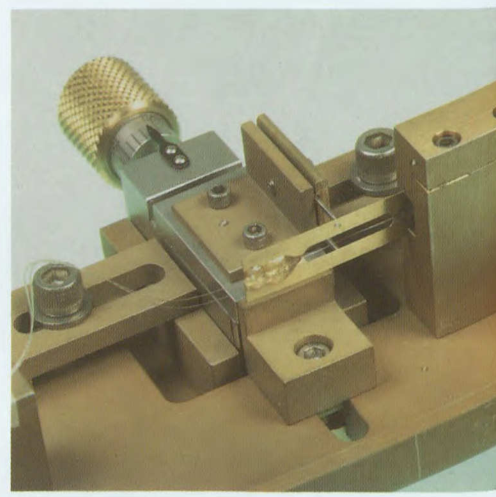
These material structures will also assist with the development of monolithic microwave integrated circuits capable of operating in the EHF band.

7. Optical Communications

Most major cities in North America are already interconnected by high-speed (1.7Gb/s) links, and other advanced countries of the world are following suit. Several fibre optic undersea cables are being installed or planned for both the Atlantic and the Pacific.

A photonic network is growing that will eventually encompass the world – with almost unlimited bandwidth for all types of users.

Current DCR research concentrates on extending the photonic network to the subscriber, looking at the most effective ways to access the 30,000 GHz of bandwidth available in a single optical fibre strand. Wavelength tunable passive components, sources and



Tunable fused coupler.

detectors are under development. The aim is to reduce costs by integrating optics and electronics on a single chip. Eventually businesses, other organizations and individuals will have access to a large variety of information and communications services through a single optical fibre connection.

8. Photonics

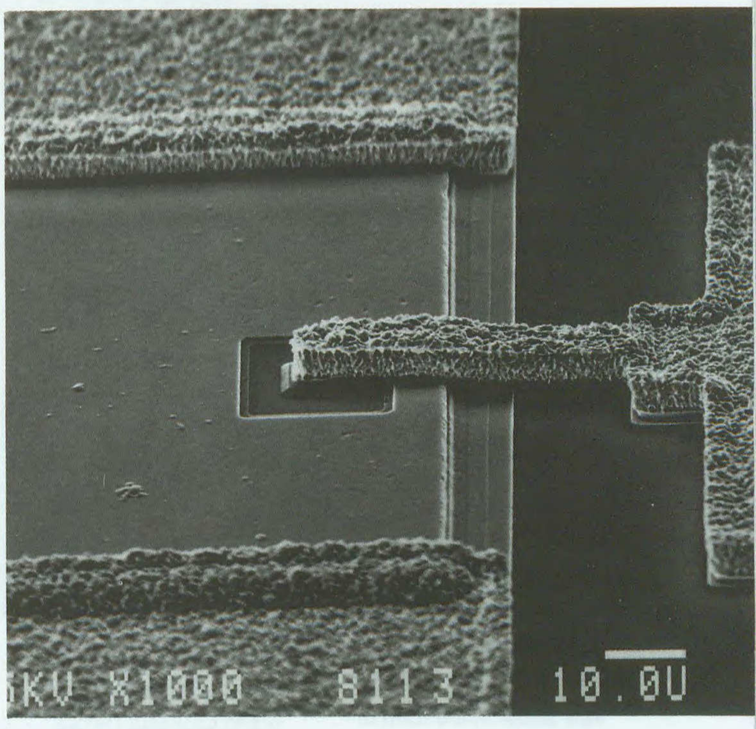
Light photons have properties that complement those of electrons. While electrons affect each other even at a distance, light beams pass through each other unperturbed unless there is a non-linear interaction. As a result, photons perform certain functions better than electrons. Their usefulness will primarily lie in information storage, processing and display. (Optical disks are already used for archival storage.) Optics can also be used for extremely large databanks – the 1-terabyte optical tape recorder, for instance. Read-and-write capability for optical storage systems is expected soon.

Because light beams do not interact, they can make many millions of parallel interconnections very easily. They are therefore potentially useful for parallel processing systems and optical neural networks.

Optical research at DCR stresses the development of non-linear materials that can be used for optical switching, optical logic and high-frequency conversion. At the levels of systems, DCR is concentrating on optical computing architectures. Essentially this research is aimed at making light perform some of the functions currently performed by electrons. If successful, the results will make feasible fast computers with parallel processing – akin to the human brain.

9. Reliability Studies

An integral part of research and development into semiconductor-based devices and integrated circuits involves the reliability – over the long term – of materials and processes.



Scanning electron microscope photo of a microelectronic component.

This is critical, because many of the devices will be used in advanced satellite and military communications systems. That means components must be comprehensively tested to be sure they will operate reliably in a great variety of environmental conditions. It is important, therefore, that new methods be developed to make such testing possible.

DCR research concentrates on trying to predict the long-term performance of gallium arsenide-based circuits in extreme fluctuations of temperature and under ionizing radiation.

TECHNOLOGY TRANSFER AND COLLABORATION

While the research carried on at Communications Canada and at DCR supports the Department's mission first of all, it is also intended to benefit the Canadian telecommunications and informatics industry. Communications Canada's Technology Transfer and Industrial Collaboration Program acts as the conduit that transfers research results to the private sector in the form of usable and commercially viable technology. DCR's contributions to the program have been notably successful in gallium arsenide technology and in microwave components.

Technology is transferred from DCR in several ways. Grant programs and other funding ventures are a major method, of which the Industrial Research Assistance Program (IRAP) is probably the best known. Under IRAP, a contribution arrangement is set up with a recipient in industry. Part of the arrangement often includes access to the laboratories and technical experts at the Communications Research Centre.

In addition, DCR contracts for research and development directly with universities and industry, transferring technology as part of the contract arrangement. Students – both graduates and undergraduates – often spend work periods in DCR's laboratories, gaining "hands-on" experience relevant to their future careers.

Mapping defects using a scanning photoluminescence system.

There are other innovative approaches that benefit Canadian research and the telecommunications industry. DCR has instituted several joint projects or "partnerships" with Canadian firms and with other research organizations to investigate various aspects of gallium arsenide technology. In these cases, memoranda of understanding cover areas of mutual interest and, in particular, protect intellectual property. In this way, DCR can share its expertise, help strengthen the competence of Canadian industry, develop new devices and circuits for special applications, and foster team arrangements between companies. Similar partnerships are also arranged with international organizations when the work clearly benefits both countries.

Technology transfer projects offer the opportunity to create many new jobs in Canadian telecommunications each year, a significant proportion of them attributable to DCR, which is continually seeking new avenues of collaboration or cooperation.

Setting up a radiation effects experiment at Queen's University.