GENERATION, DETECTION AND PROPERTIES OF COHERENT RADIATION OF WAVE-LENGTHS LESS THAN 1 MM

THE autumn meeting of the British Radio Spectroscopy Group was held at Bournemouth, Hampshire, during September 24–25. The meeting was concerned with the generation, detection and properties of coherent radiation of wave-lengths less than 1 mm. Nineteen papers were presented during three sessions while the fourth session was taken up with a visit to the Quantum Physics Division of the Signals Research and Development Establishment, Christchurch, Hampshire.

Mr. R. J. Lees, director of the Signals Research and Development Establishment, who gave the address of welcome to the 130 delegates, comprising approximately 45 from the universities, 55 from industry and 30 from Government service, saw the essential function of the meeting to enable the delegates to exchange ideas on mutual interests, so forming cross-linkages between the various sections of this wide field.

The nineteen papers presented can be divided into four general groupings, eleven on generation, two on detection, three on spectroscopy and three concerned with gaseous lasers. As can be seen, the generation of sub-millimetre radiation attracted the most attention.

M. G. Convert (Compagnie Générale de Télégraphie sans Fil) discussed the main design features: beam geometry, beam velocity and construction of the elements that have to be considered in the development of a carcinatron. The power output, which depends approximately on the reciprocal of the frequency squared, is limited by the imperfections in them together with any ohmic losses. Results were presented of output power against wave-length for a range of values. In particular the 0·5-mm carcinatron gave a few milliwatts and had a 10 per cent tuning range.

Dr. K. D. Froome (National Physical Laboratory, Teddington) outlined the design of his plasma–metal junction harmonic generator. It rectifies and therefore generates harmonics by field emission from a liquid platinum cathode due to the proximity of a very dense plasma. This plasma is formed in an argon–hydrogen atmosphere at high pressure and has an ion density that has to be kept to less than 10^{20} in order to avoid back conduction. When the junction was driven with 10 W at 8·5-mm, 0·3-mm radiation, the twenty-ninth harmonic, was generated.

The construction and operation of such a generator as a tunable source in a high-resolution sub-millimetre spectrometer was described by Mr. J. Knapp (Queen Mary College). It was found not practical to use it in an automatic scan system. Dr. A. J. Bastin (Queen Mary College) reported measurements made by a number of workers, including himself, of atmospheric absorption in the sub-millimetre region. These measurements showed that atmospheric absorption was due to: (1) water vapour broadened by nitrogen collisions; (2) water droplets of varying radii; (3) oxygen, ozone and other trace gases; (4) collision-induced absorption between oxygen and nitrogen atoms. It was commented that more experiments were needed in which some attempt had been made to match path-length to absorption coefficients.

Mr. G. S. Waters (Signals Research and Development Establishment) described the construction and operation of an optical line-of-sight communication link using a helium neon laser on 6328 Å as source. Measurements were made comparing the laser as a source with a mercury-arc lamp, both being shone 'backwards' through a mirror telescope over 1,300 yd. The results showed that the spatial coherence of the laser made the laser superior to the arc lamp for ranges longer than 300 yd. The laser's narrower line-width seemed to be only of secondary importance. Dr. D. C. Laine (Keele) examined the feasibility of an ammonia maser oscillating at 0·125 mm on the $J = 4$, $K = 3$ to $J = 3$, $K = 3$ rotational transition. A relation was derived giving the minimum number of molecules required per sec for oscillation threshold. The substitution of values into this relation gave that the number required was a factor two thousand times larger than the number needed in the microwave case. This factor can only be obtained by the use of multiple beams.

Dr. J. G. Baker (Bristol) discussed the spectroscopy of short-lived free radicles and gases in the lower millimetre and sub-millimetre regions. A free-space absorption cell suitable for the observation of electric and magnetic rotational transitions, many of which fall in these regions, was described together with a superheterodyne system of detection. Mr. A. W. Horsley (Standard Telecommunication Laboratories, Ltd.) discussed two possibilities for generating sub-millimetre radiation using bulk non-linear properties of semi-conductors. The first rested on charge density gradients and electric field gradients in the semiconductor giving rise to harmonic currents. The second involved the mixing of axial modes in laser beams by an extension of Pantell's centimetre wave mixing techniques. Mr. C. H. Carmichael (Signals Research and Development Establishment) proposed the use of a Fabry–Perot etalon within the parallel mirror resonant cavity of a laser to suppress the emission except within the narrow pass bands of the etalon. Then with a laser material, the fluorescence line width of which is 10 cm^{-1} or greater, the plate separation of the etalon can be chosen to yield frequencies, which, when mixed in a suitable non-linear system, will yield sub-millimetre radiation.

Mr. I. B. Bott (Radar Research Establishment) described the construction of a tunable source of millimetre radiation 0·93–2 mm. Electrons, when injected into an axially symmetric magnetic field, undergo cyclotron resonance and the radiation emitted in a strong forward lobe is partially coherent. In the case described the field was pulsed to 100 kG and remained reasonably steady for 7 msec. The output at 1·1 mm was 1 mW. Mr. A. H. Beck (Cambridge) suggested that a spiralling electron beam when synchronized to an electric field having the correct time dependence should be a method of generating millimetre radiation. Mr. P. M. Robson (Sheffield) suggested that millimetre radiation could be generated by Doppler shifting radiation from a moving mirror of low-voltage electrons. If the electrons were to be bunched at the matching frequency then both the electron mirror's reflectance would be increased and there would be some harmonic output. Dr. J. V. Jelley (Atomic Energy Research Establishment) discussed the use of Čerenkov radiation as a source of sub-millimetre waves. A Fourier analysis of the radiation produced as electrons are fired through a dielectric shows that there is a component at a sub-millimetre frequency. This component may be enhanced by bunching the electrons at the required frequency. This method has produced 20 μW at 1·6 mm.

Mr. M. A. C. S. Brown (Radar Research Establishment) described two possible tunable detector mechanisms; one depending on changes in number of carriers and the other depending on changes of carrier mobility. Both these mechanisms are suitable for use in narrow band far infrared detectors. A description of the indium antimonide detector was given together with its narrow-band characteristics.

Dr. M. R. Brown (Signals Research and Development Establishment) gave a brief report on the observation of infra-red quantum counter action in praseodymium doped fluoride lattices at room and liquid nitrogen temperatures. It was hoped to use the reported schemes as a basis for the development of an infra-red detector. Mr. D. M. Clunie (Services Electronics Research Laboratory) reported results of some experiments on helium–neon gas mixtures in which more power was obtained under pulsed conditions than under continuous excitation. This was attributed to the population in the laser terminal level being higher under the continuous excitation. Furthermore, by having two sections separately pulsed at 2·5 kc/s a continuous output at 0·25-W mean level was obtained. Doubling of the infra-red outputs in ammonium dihydrogen phosphate to give a yellow spot was announced. Mr. J. Smith (Mullards) reported gain measurements made in helium–neon gas mixtures using the 1·15μ laser line. It was found that the optimum gain in the negative glow region of a cold-cathode glow discharge within a hollow cathode was achieved at much higher pressure (20-mm mercury) and higher helium to neon ratios (1,280 : 1) than those used in radiofrequency or direct-current positive column excited devices.

Dr. E. L. Thomas (Signals Research and Development Establishment) explained the stimulated Raman effect and its use in the generation of radiation. When benzene is placed inside the resonant cavity of a ruby laser, stimulated Raman radiation is produced 991 cm^{-1} away from the ruby frequency. A second Raman radiation can also be generated approximately 1,982 cm^{-1} away. The sub-millimetre radiation, in this case 0·01 mm, would then be generated by mixing the Raman radiation with the ruby radiation.

Dr. D. H. Martin (Queen Mary College) reviewed the kinds of spectra that can be observed in solids with sub-millimetre radiation. These ranged from lattice absorptions in ionic lattices (30μ for lithium fluoride) to anti-ferromagnetic resonance (1·2 mm for manganous fluoride).

M. R. Brown

THE GEOLOGISTS' ASSOCIATION

SEVERAL important geological finds made during 1963 were among the exhibits shown at the annual reunion of the Geologists' Association held in the Large Hall of Chelsea College of Science and Technology on November 2.

The most outstanding of these discoveries was the remains of a large pliosaur from the Oxford Clay exhibited by the Department of Palæontology, British Museum (Natural History). This comprised a right-hand paddle 7 ft. 6 in. in length. Many pliosaurs have been found in the Oxford Clay especially near Peterborough[1]. However, complete specimens of large pliosaurs lying *in situ* are rarely come by. It is thought their size prevented them from quickly sinking in the mud and hence they were eaten by their fellow scavengers. The pliosaur was found in the London Brick Company's clay pits at Stewartby, Bedfordshire, during June 1963, but the front half of the reptile had been taken away by the digger before the bones were noticed. Some of them were later recovered from the spoil heap by a party from the British Museum (Natural History), and the London Brick Co. has presented the remains to the Museum. It is hoped that the whole reptile will be recovered. The British Museum (Natural History) also showed dinosaurian footprints from the Purbeck, Devonian trilobites from the Spanish Sahara and cobalt pellets from the stomachs of sheep.

In 1961 the longest continuous trackways yet found were discovered in a quarry at Herston on the outskirts of Swanage, and in June 1963 after the overburden had been removed 75 ft. of trackway was exposed. Until now it has been generally assumed that these footprints were made by the herbivorous bi-pedal dinosaur, *Iguanodon*. But, as shown by the exhibit, it is apparent that the bird-like prints forming the main trackway are more akin to a bi-pedal carnivorous dinosaur, such as *Megalosaurus*. Until recently, trilobite remains were almost unknown from the Spanish Sahara, but during oil exploration work there E. Rod collected almost 30 specimens. The best were given to the British Museum. They came from strata of the Middle Devonian and all belong to the genus *Phacops*. With the exception of a single specimen they belong to one species, probably new but related to *P. papulatus* from Morocco. The remaining specimen is a related form but is distinguished by a finer ornamentation of the test and a large number of eye facets.

S. E. Ellis (Department of Mineralogy) exhibited phosphate minerals deposited on cobalt pellets from the stomachs of sheep. The sheep is subject to a disease known as 'pining' due to a deficiency of cobalt in herbage. This is combated by either the expensive method of spraying or inserting into the young lamb's stomach a pellet of baked clay impregnated with cobalt oxide.

Ammonites and literature recently acquired in the U.S.S.R. were among the items shown by the Geological Survey and Museum. Ammonites are very important in the identification of zones or sub-zones, which are often named after them. They included the following species from the Upper Aptian of the Lower Greensand (Lower Cretaceous): *Parahoplites melchioris*, *Colombiceras caucasicum* and *Australiceras ramososeptatum*.

J. N. Carreck (Queen Mary College, London) showed specimens, maps, etc., illustrating copperas, as vanished Kentish industry. From about A.D. 1320 until 1914, copperas (an obsolete name for ferrous sulphate or green vitriol) was manufactured from iron pyrites occurring in the London Clay (Lower Eocene) on parts of the coasts of Essex[2], Kent, Dorset and, perhaps, Hampshire. It was used for the preparation of sulphuric acid, black ink and dye (both as a pigment and a mordant), dressing leather, as a sheep die, for the making of paints—prussian blue (ferric ferrocyanide) and spanish brown (ferric hydroxide), and after refinement was in much demand among both apothecaries and physicians. Mrs. Carreck exhibited photographs of past and present members of the Association.

Dr. G. P. L. Walker (Imperial College of Science and Technology, London) showed several xenoliths of wood collected from Tertiary basalt larvas. He explained how timber, when enclosed in basalt, chars and the basalt is consequently injected into the network of contraction cracks which result. Sometimes the charred wood survives; at other times it is fossilized, for example, replaced by zeolites; or it disappears to leave cavities in the basalt and these may afterwards be infilled with zeolites, etc.

With the west Weald earthquake of October 25 and the Glen Spean earthquake of August 31 still in the news, Dr. A. T. J. Dollar (Birkbeck College, London) exhibited a map illustrating the intensity of the quakes, together with data based on reports from observers of the British Earthquake Enquiry. Other earthquakes demonstrated in the same manner were those occurring in the County of Inverness in 1947 (ref. 3) and the Midlands in 1957 (ref. 4). Together with F. G. Berry, Dr. Dollar also showed a new hand-operated continuous coring tool with a sample core.

A. G. Nicholson showed specimens illustrating the geology of the Lizard Peninsula. These included the 'serpentine' of the local lapidaries which is the altered