D1. Solid State Microwave Sources

Several types of compound semiconductor devices, such as MESFETs, HEMTs, and HBTs have increased in output power, gain, power-added efficiency, $f_{\text{max}}$ and $f_t$. In Ku band, initially matched GaAs MESFET with multi-chip power divider/combiner technology has an output power of 43.2 dBm with a 6.9 dB gain [Saito et al., 1995]. A sub-half micron WSi/Au T-shape gate HFET provided an output power of 11.2 W and a power-added efficiency of 41 % [Udomoto et al., 1995]. High power multfinger HBT has been realized by using emitter ballasting resistors and a PHS structure. It achieved an output power of 1 W with power added efficiency of 72 % [Shimura et al., 1995]. In the millimeter-wave region, the 2400 mm HFET is also highly efficient and has a high output power of 1 W with a gain of 4.4 dB and power added efficiency of 30.1 % at 42 GHz [Arai et al., 1995]. The InP/InGaAs double-heterojunction transistor with InGaAsP in the collector has an $f_{\text{max}}$ of 267 GHz with a 0.8-mm emitter metal [Yamahata et al., 1994].

HEMT or HJFET-based MMICs have been developed around the 60-GHz band for short-range wireless communications and sensing systems, such as high-speed wireless LANs, RF-ID systems, automotive radar systems, and so on: Using AlGaAs/GaAs HJFET with a 0.15-mm T-shapped gate, a single stage MMIC power amplifier has achieved an output power of 37.2 mW with a 25.6 % power added efficiency [Funabashi et al., 1993]. A dielectrically stabilized monolithic voltage controlled oscillator with a buffer amplifier has achieved an output power of 6.9 dBm, -80 dBc/Hz at 100 kHz off-carrier, and -4.1 ppm/C. The VCO was fabricated AlGaAs/GaAs HJFET [Inoue et al., 1995]. Using 0.11-mm InGaP/InGaAs/GaAs HEMT technologies, fully integrated MMIC receiver has been fabricated which consists of low-noise amplifier, single balanced active mixer and local oscillator. It has a conversion gain of 20 dB and a noise figure of 6 dB [Saito et al., 1994]. A fully monolithic chip for an RF-ID system has been developed. It has a direct-detection receiver with a two-stage low noise amplifier and direct ASK modulatable transmitter [Ono, et al., 1995].

The HEMT and HEMT-based MMIC was implemented in subsystems up to W-band: In 91 GHz, a six-stage low-noise amplifier with three cascaded two-stage AlGaAs/InGaAs/GaAs P-HEMT-based MMICs has achieved a noise figure of 4.3 dB with a gain of 28.1 db [Itoh et al., 1995]. A 94 GHz low-noise converter with MIC technology has been developed by combining an InP-HEMT low-noise amplifier, a P-HEMT mixer, and a dielectric resonator oscillator. It shows a noise figure of 4.9 dB and gain of 11 dB [Yoshinaga et al., 1993].

In order to realize low-cost microwave and millimeter-wave communications equipment, a novel MMIC and interconnection technology are being developed: An MMIC chip size can be reduced and the integration level increased using a multi-layer polyimide film on a GaAs wafer. The so-called three-dimensional MMIC was used in an 8 dB amplifier in the X band. The chip size of 0.65x0.6 mm is less than 1/3 of the conventional [Tokumitsu et al., 1995]. The millimeter-wave flip-chip IC (MFIC) has been operated up to 60 GHz. Flip-chip transistors are connected to microstrip lines on a Si substrate with micro bumps [Sakai et al., 1994].
References


Tokumitsu, T., and M. Aikawa, Design and fabrication techniques in recent MMIC’s, MWE'95, 191-194 (1995)


Yamahata, S., K. Kurishima, H. Nakajima, T. Kobayashi, and Y. Matsuoka, Ultra-high f max and f t InP/GaAs double-heterojunction bipolar transistors with step-graded InGaAsP collector, IEEE GaAs IC Symp., 345-348 (1994)


D2. Gas and Solid-StateLasers
The AMMTRA project has reached its final goal in 1993, in which a high repetition rate of 5 kHz with an average power of 560 W in a XeCl excimer laser [Goto, et al., 1995], a high output power of 2.1 kW at 800 Hz with an efficiency of 3.0 % in a XeCl excimer laser [Sato, et al., 1995], a high power stability of +0.9 % over 8 hours with an average power of 400 W in a XeCl excimer laser, a long gas lifetime of $10^9$ shots in an ArF excimer laser [Saito, et al., 1994], and a spectral linewidth of 0.8 pm with an average power of 250 W in an ArF excimer laser [Komori, et al., 1995] were achieved. A spectral narrowing KrF excimer laser, with a linewidth below 1.5 pm, was presented for a light source in the commercial production of 64 Mb and 256 Mb DRAM [Kowaka, et al., 1993]. 1 kHz operation in a very compact ArF excimer laser was demonstrated [Sekita, et al., 1994].

Small-signal gain, saturation intensity [Kakehata, et al., 1992], and small-signal absorption [Kakehata, et al., 1994] of a discharge pumped F2 laser (157.6 nm) were measured. The small-signal net gain has reached 37+-4 %/cm at an excitation rate of 26 MW/cm$^3$, and it was showed that MOPA configuration was more favorable for F2 lasers in order to obtain better efficiency. The sum of a transient absorption was 2.5 %/cm and the stationary absorption was 0.5 %/cm. An injection-seeded unstable resonator was applied to a discharge-pumped F2 laser in order to improve beam quality [Kakehata, et al., 1993].

Adoption of the unstable resonator for an e-beam pumped argon excimer laser (126 nm) achieved successful operations of a high output energy of 28 mJ without any damage of the resonator mirrors [Kateto, et al., 1995].

A numerical model has been developed to describe fundamental output characteristics of the Xe Auger laser (109 nm) pumped by soft X-rays from a laser-produced plasma [Kubodera, et al., 1995].

Stable generation of a narrow divergence X-ray laser beam in double-pass amplification with a curved-slab target has been demonstrated in Ne-like Ge lasers (J=0-1 line at 19.6 nm and J =2-1 at 23.6 nm) [Kodama, et al., 1994]. Significant improvement in the efficiency and brightness of the 19.6 nm line of the germanium laser by double-pulse pumping of a curved target [Daido, et al., 1995a]. Efficient soft X-ray lasing with multiple infrared pulse pumping of a curved target has been demonstrated in Ni-like elements covering the spectral range between 6 and 8 nm [Daido, et al., 1995b]. The first observation of the amplification of spontaneous emission on the Lyman-transition (13.5 nm) in H-like Li ions, using a novel optical-field-induced ionization (OFI) scheme. In their OFI scheme, singly ionized lithium ions, initially prepared by a nanosecond KrF excimer laser, are further ionized to a fully stripped state by a subpicosecond high-intensity KrF laser ($10^{17}$ W/cm$^2$), and a small signal gain coefficient of 20 cm$^{-1}$ was obtained [Nagata, et al., 1993, 1995], [Midorikawa, et al., 1995].

An average laser output power as high as 5 kW has been produced from a TEA CO$_2$ laser pumped with a new solid state exciter [Hatanaka, et al., 1993]. The maximum repetition rate of 1.1 kHz was achieved for the average laser power of 3.4 kW, and an overall efficiency was 10.5 %. Continuous frequency tunability in the 1.4 GHz has been demonstrated for the injection-locked TEA CO$_2$ laser using an acousto-optic frequency shifter inside the cavity [Suda, et al., 1994].

Wavelength region of solid-state lasers have extended by using nonlinear crystals and new laser materials. A laser system tunable from 198 nm to 450 nm was realized by sum-frequency mixing and harmonics generation of pulsed Ti:sapphire laser [Meguro et al., 1994]. UV light of 399 nm were generated with high efficiency of over 70 % by second harmonics of Ti:sapphire lasers [Watanabe et al., 1994]. A broadband amplification around 327 nm was demonstrated with Ce:LuLiF$_4$ crystal [Sarukura et al., 1995]. A gain of 15 %/cm at 2.05 mm was obtained
with Tm, Ho co-doped alumino-zirco-fluoride glass [Doshida et al., 1995]. The high power of 24 W at 532 nm was achieved by second harmonics of Nd:YAG laser [Kojima et al., 1994].

A continuous wave (cw), 266 nm ultraviolet source of all solid-state was developed for semiconductor process application [Oka et al., 1995]. A cw 26.5 W, TEM00-mode LD-array-pumped Nd:YAG Laser was demonstrated with novel side pumping configuration of the virtual-point-source [Uehara et al., 1995].

(K. Kobayashi)

References


Oka, M., and S. Kubota, Applications of continuous-wave deep ultraviolet lasers, CLEO'95, 139 (1995)


Sekita, H., and S. Ito, 1 kHz high repetition Rate operation for an ArF excimer laser, CLEO'94 (1994)


D3. Semiconductor Lasers and Detectors
Long-wavelength InP-based distributed feedback (DFB) laser with a multiquantum-well (MQW) electro-absorption modulator [Aoki et al., 1995] have been intensively studied for possible application to 10-Gbit/s long-haul optical fiber transmission systems. Wide temperature range (WTR) operation of direct-modulated DFB lasers was achieved by employing a strained-MQW active layer [Furushima et al., 1995; Aoki et al., 1995], which enables the laser to operate without thermo-electric coolers. An ultra-narrow (3.6 kHz) spectral linewidth has been demonstrated by successfully suppressing spatial hole burning [Okai et al., 1993], and wide wavelength tuning of 105 nm has been attained by using a special grating, i.e., a super structure grating (SSG) [Tohmori et al., 1993]

Fabry-Perot laser diodes for use in access networks have been extensively researched, and the following milestones have been attained: 1) a low threshold current of less than 1 mA [Uomi et al., 1994] [Terakada et al., 1994], 2) WTR-operation up to 165 C [Aoki et al., 1995], 3) narrow-beam divergence (10 deg.) [Wada et al., 1995; Yamamoto et al., 1995], and 4) fabrication of a low-threshold monolithic laser array with a 1-mA range for optical interconnection [Uomi et al., 1995; Nishimura et al. 1993].

Research on vertical cavity surface emitting laser diodes has achieved ultra-low threshold (70 mA) operation [Hayashi et al., 1995] and CW-RT operation of a long-wavelength laser [Baba et al., 1993]. Also, high-power and highly reliable operation has been demonstrated in 980-nm laser [Sagawa et al., 1995; Ishikawa et al., 1995], and a high-speed 650-nm laser diode has been used for 2.5-Gbit/s transmission with GI-POF [Yamazaki et al., 1994].

Short wavelength laser diodes are also very important as light sources for high-density information-processing systems. The first CW-RT operation of a wide-gap II-VI laser was at a wavelength of 523.5 nm [Nakayama et al., 1993]. The quantum efficiency of GaN-based green LEDs was drastically improved by employing an InGaN SQW active layer [Nakamura et al., 1995].

High-speed 110-GHz pin-photodiodes and avalanche photodiodes with a gain-bandwidth of 120 GHz have been realized by using a waveguide-type structure [Kato et al., 1994; Shishikura et al., 1995]. A 0.95 W/A waveguide photodiode that can be used without coupling lenses has been developed for low-cost optical module applications [Akatsu et al., 1995].

(M. Nakamura)

References


Furushima, Y., Y. Sasaki, T. Murakami, and H. Hasumi, Wide temperature operation of 1.3 mm
strained MQW 1/4-shifted DFB-LDs for 2.5 Gb/s transmission modules without temperature control, ECOC’95, 537-540 (1995)


Sagawa, M., T. Toyonaka, K. Hiramoto, K. Shinoda, and K. Uomi, High-power highly-reliable operation of 0.98-mm InGaAs/InGaP strain-compensated single-quantum well lasers with tensile-strained InGaAsP barriers, IEEE J. Selected Topics in Quantum Electron, 1, 189-195 (1995)


Terakado, T., K. Tsuruoka, T. Ishida, T. Nakamura, K. Fukushima, S. Ae, A. Uda, T. Torikai, and T. Uji, Extremely low threshold (0.4 mA @20 C, 3.0 mA @85 C) 1.3-mm strained-MQW lasers with novel p-substrate buried-heterostructure grown by MOVPE using TBA and TBP, 14th IEEE International Semiconductor. Laser Conf., paper PD9 (1994)


D4. Laser Applications

Remarkable progress has been achieved in high capacity WDM transmission experiments by using wideband EDFAs and dispersion compensating fibers or dispersion-shifted fibers at 1.55 mm wavelength region. Tera-bit/s WDM transmissions have been achieved (55 wavelengths x 20 Gb/s over 150 km [Onaka et al., 1996] and 10 wavelength x 100 Gb/s over 40 km [Morioka et al., 1996]). In the TDM area the most widely researched photonic integrated circuit is a DFB laser integrated with an electroabsorption modulator. Recently a device with 20 GHz bandwidth modulation and 22 dB on/off with only 2 V peak-to-peak drive has been reported [Wakita et al., 1994]. Soliton transmission technology has also advanced with the use of EDFAs. High speed soliton transmission experiment has also been demonstrated. Soliton pulses at an 80 Gb/s rate have been propagated over 500 km with periodic EDFAs and an EDF ring laser source [Nakazawa et al., 1994] and some soliton transmission field tests have been reported [Nakazawa et al., 1995].

Optical analog transmission technology for CATV applications has show much progress. In order to improve the yield of DFB laser a novel partially corrugated design has been developed [Okuda, 1994]. Microcellular radio communication system which is the other major application of analog laser has also advanced [Saito et al., 1995] [Watanabe et al., 1995].

Progress has been made in photonic switching technology and optical computing research. As for photonic switching technology, a 1 x 2000 switch has been developed and used in automatic optical fiber operations support system of NTT [Tomita et al., 1996]. Optical computing researches have been done mainly under the national project: RWCP [Shimada, 1995]. Concerning laser diodes for optical information processing, remarkable progress has been achieved in vertical cavity surface emitting lasers [Iga, 1994].

(A. Ishida)

References

Iga, K., Prospects of surface emitting lasers, JIEICE, 77, 1263 (1994)

D5. Solid State Memories

The 256 Mb DRAM have now gone to the first prototype stage [Watanabe et al., 1995] and the 1 Gb DRAMs have gone to the first experimental stage [Horiguchi et al., 1995; Sugibayashi et al., 1995]. For realizing low power and low voltage DRAM, small bit-line swing scheme [Inaba et al., 1995; Hamamoto et al., 1995], a power-off mode [Takashima et al., 1995] and elastic voltage CMOS circuit scheme [Takashima et al., 1993] were developed. DRAMs with fast operation modes such as cache DRAM, synchronous DRAM, rambus DRAM [Ohshima et al., 1994] could be major products to follow the clock cycle progress in MPUs.

In the last decade the flash memory technology has made significant achievement, with memory densities increased from 256 Kb to 32 Mb. The one-bit-per-cell 32 Mb flash memories with NAND cell structure [Imamiya et al., 1995] and with AND device [Nozoe et al., 1995] were developed with 0.4-0.5 mm design rule.

The trend toward faster access time was very evident in high density CMOS SRAM. Utilizing 0.25 mm design rule 300 MHz 4 Mb CMOS SRAM [Ishibashi et al., 1995] were developed as an external cache memory for next-generation RISC microprocessors. BiCMOS SRAM have also advanced; 220 MHz 16 Mb BiCMOS SRAM [Nakamura et al., 1994].
(A. Kasami)

References


Takashima, D., S. Watanabe, K. Sakui, H. Nakano, and K. Ohuchi, Stand-by/active mode logic for sub-1 V 1 G/4 Gb DRAMs, Symposium on VLSI Circuits Dig. Tech. Papers, 80-81 (1993)


D6. Cryoelectronics

A Josephson 4-K bit RAM with vortex transitional cells was developed by 1.5 mm technology with approximately 21,000 Nb/AlO$_x$/Nb Josephson junctions to show the performance of a record high access speed of 380 ps, a power dissipation of 9.5 mW, and a bit yield of 98.6% [Nagasawa et al., 1994, 1995]. To improve the performance of multi-processor systems, a superconducting ring-pipelined network system was proposed. By use of 1,130 high-speed Josephson gates, the prototype design led to the estimation of a clock frequency of 10 GHz and a system throughput of 60 Gbps [Tahara et al., 1995]. A superconducting three terminal device was demonstrated using a Nb based proximity structure where two niobium electrodes were linked with a 0.2-0.6 mm long InAs-based two-dimensional electron gas heterostructure [Takayanagi et al., 1994]. The critical current was controlled by gate voltage, exhibiting a novel oscillating behavior [Takayanagi et al., 1995]. A superconducting neural circuit was demonstrated using a combination of a Nb/AlO$_x$/Nb 1J-SQUID and a 2J-SQUID as a neuron element and multiple 2J-SQUIDs as a synapse [Mizugaki et al., 1993]. A 3-bit A/D converter was demonstrated using this type of superconducting neural circuits [Mizugaki et al., 1995].

A 16-channel high-$T_c$ SQUID system operating with liquid nitrogen was developed [Itozaki et al., 1994]. Each SQUID was made of a YBa$_2$Cu$_3$O$_7$ step-edge weak link Josephson junction and exhibited a magnetic field resolution of 370 fT/Hz$^{1/2}$ at 10 Hz and 220 fT/Hz$^{1/2}$ at 10 kHz with the use of a flux focusing plate. This system was applied to cardiography to obtain magnetocardiogram of a human heart and thereby a magnetocardiac isofield contour map of a 12 cm square chest region. The mixing performance was demonstrated using a YBa$_2$Cu$_3$O$_7$ step-edge weak link Josephson junction in the 700 GHz frequency range with the local oscillation of 100 GHz, producing an output of 1.55 GHz, a beat frequency of 692.95 GHz and the 7th harmonic of 98.772 GHz [Shimakage et al., 1995]. This experiment employed a quasi-optical configuration using a hyperhemispherical lens with the step-edge junction on its flat surface. A superconducting three-terminal device was developed with an In/(Ba, Rb)BiO$_{1.3}$/SrTiO$_3$(Nb) structure. This device provided the performance of a common-base current gain of $\alpha=0.94$ and a common-emitter current gain of $b=10$ [Toda et al., 1994]. An SIS type current-voltage characteristics with a clear superconducting gap structure were observed for a stack of intrinsic Josephson junctions fabricated on the surface of a Bi$_2$Sr$_2$CaCu$_2$O$_8$ single crystal [Suzuki et al., 1995]. This was made possible by reducing the number of series junctions to less than 40 (60 nm), by which the nonequilibrium heating effect was significantly suppressed. A frequency down-conversion in the 23 GHz range was also demonstrated using a 20 mm square MgO plate on which a Josephson weak link and a patch antenna were integrated [Suzuki et al., 1994]. This system employed a Josephson weak link fabricated using a focused Ga-ion beam technique. As a more fundamental but novel high-$T_c$ superconducting device, it is noted that a photo-sensitive bicrystal Josephson weak link was developed and the modulation of the critical current by 632.8 nm light irradiation was demonstrated [Tanabe et al., 1994].

(M. Suzuki)

References


**D7. Acoustic Devices**

In microwave communication systems, the insertion losses of filters are required to be small. Low-loss surface-acoustic-wave (SAW) filters for mobile telephones were developed at 900 MHz [Morita et al., 1992] and at 1.9 GHz [Ikata et al., 1992] by using the conventional resonators. The narrow passbands of SAW resonator filters were improved by using new structures, and an intermediate-frequency filter at 250 MHz was developed [Yamamoto and Kajihara, 1993]. A low-loss SAW filter was also developed at 4 GHz by using unidirectional transducers [Yamanouchi et al., 1992]. For high-power transmitters in mobile telephones, SAW resonator filters were developed and used instead of the conventional bulk-acoustic-wave filters [Hikita et al., 1993, 1995].

Acoustic devices can be used for sensors in natural and industrial applications. A multi-channel chemical gas sensor was developed by using SAW resonators [Moriizumi et al., 1994]. A device
for sensing the humidity in the air was developed, which consisted of a pair of SAW delay lines [Nomura et al., 1994]. A similar sensor for using in the liquid phase was developed, which distinguished the sources of natural water [Kondoh et al., 1994].

Acoustic vibrators are the key devices of ultrasonic gyroscopes, which are used in video cameras and car navigators. A high-sensitive gyroscope was developed by using a crystal fork vibrator [Wakatsuki et al., 1994]. The size of a gyroscope was reduced by using a cylindrical ceramic vibrator, which was appropriate for mass production [Shuta and Abe, 1995].

(M. Hirabayashi)

References


