Gallium-Arsenide

Lasers and Emitters

OPT-100

Optional Price 25 Cents

Introduction

This brochure contains a concise description of the RCA line of solid-state emitters, including infrared emitters, single- and multiple-diode lasers utilizing either gallium arsenide or gallium aluminum arsenide junction materials.

The indicated breadth of this product line assures you of RCA's capability of providing a device suitable for your application. Information on special and custom devices tailored to your specific application requirements can be obtained by contacting any of the RCA sales offices listed on the back cover of this brochure.

Emitters & Lasers ... A General Description

The junctions of all semiconductor diodes will emit some radiation if the devices are forward-biased. This radiation is the result of energy released when electrons and holes recombine in the junction.

Certain semiconductor materials such as gallium arsenide have unique physical characteristics and emit relatively high levels of radiation with reasonable power efficiency.

There are two distinctly different types of semiconductor diode emitters:

1. Diodes which produce spontaneous emission when forward-biased.

2. Diodes which, under certain drive conditions, maintain a mode of operation known as lasing.

In this brochure, diodes in the first category are referred to as "emitters," and diodes in the second category are classified as "lasers." By strict definition, the term emitter is quite general and could be used to describe all emitters, including laser devices. For reference, other designations often used for these solid-state radiant devices are:

Emitter Classification
Light-emitting diode (LED)
Non-coherent emitter
Spontaneous emitting diode
Optical diode

Laser Classification
Solid-state laser*
Coherent laser diode
Injection laser diode
Semiconductor laser*

Lasers and emitters have very different operating characteristics. Table I contrasts the devices. Table II is a quick-selection guide to the right type of device (based on general operating characteristics). The Applications Section includes a table which provides recommendations for specific devices for typical applications.

One operating characteristic which lasers and emitters have in common is output wavelength. The output wavelength is important because it determines the suitability and sensitivity of the detectors for the application. The wavelength of the radiation produced by an emitter, or a laser, is an inherent property of the semiconductor material; see Fig. 3. It is alterable to some small extent by doping during manufacture and it is sensitive to junction temperature changes (2½ A/°C). Because efficiency is also closely related to the material, only certain wavelengths are efficiently generated. A range of wavelengths can be generated from certain 3-element (ternary) materials by changing the ratio of two of the three component elements. This should not be confused with doping of binary compounds as it is a much more involved process. See Fig. 3 for a comparison of the wavelengths produced by various emitting devices and the response of the human eye.

*These terms are also used to describe lasers such as ruby, neodymium or YAG.

Emitter Characteristics

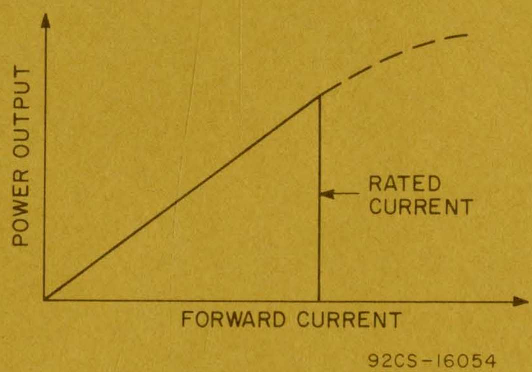

Fig. 1 Power output vs. forward current for a typical emitter.

The emitter is the simpler of the two devices; it is a semiconductor diode which emits radiation when forward biased. The radiation starts at low values of forward current and increases nearly linearly until dissipation-limited by the junction temperature (which is usually beyond the normal operating range); see Fig. 1.

Emitters may be operated in either continuous or pulsed service. The emission mechanism is very fast, thereby permitting modulation at frequencies into the megahertz region.

Emitters made of GaAs are the most efficient, e.g., 2%. Most of the losses occur at the GaAs-to-air interface.

Methods of reducing these losses result in three subclasses of emitters named for the area of the semiconductor where the radiation is emitted: edge emitter; surface emitter, and dome emitter. Each represents some compromise in performance and cost. A comparison is given in Table III.

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Table I
Comparison of RCA Lasers & Emitters

Values in shaded areas are for cryogenic operation.

Characteristic	Emitter	Laser	Comparison
Peak Output Power	1 to 24 mW	1 to 23 W (Peak)	Laser 1,000x greater
Av. Radiant Output Power	1 mW 5 mW	1 to 13 mW (Av.) 1 to 60 mW	Laser slightly greater
Power Efficiency	2% 20%	4% 40%	Nearly the same
Operating Duty Factor	any	0.1% 2%	Lasers always pulsed Emitters usually CW
Output Emittance (Power Density)	40 W/in.^{2}	20,000 W/in.^{2}	Laser better by 500x
Beam Profiles	Varies with construction	Constant due to diffraction	Similar
Spectral Width	400 Å	10 Å	Laser has smaller spectral width

Table II
Quick-Selection Guide

1. Choose an Emitter	– any time duty factor must exceed 2%. – any time pulse duration must exceed 2 μs. – for any application requiring CW operation.
2. Choose a Room Temperature Laser	– when high peak power is required.
(a) Choose a Single-Diode Laser	– for all high repetition-rate applications.
(b) Choose a Laser Stack	– when high power density is more important than repetition-rate. – when narrow beams of more power are needed.
(c) Choose a Laser Array	– when very high peak power is most important. – when fan-shaped beams are required.
3. Choose a Cryogenic Laser Array	– when high average power is required. – when duty factor is 0.1 to 2%.

Table III

	Edge Emitter*	Surface Emitter	Dome Emitter
Particular advantage	Most value in small emitters	Greatest value in large emitters	Greatest output
Emission pattern	360° (circle) out of edges of junction	Out one side with cosine distribution over hemisphere	Out of hemisphere with uniform distribution over hemisphere
Radiation collection	Parabolic reflector	Lens	Parabolic reflector
Disadvantages	Only applicable to low-power emitters	Poor collection of emission	Difficult to manufacture

*In certain applications such as line finders and edge sensors, the unique line of emission generated by the edge emitter can be an important advantage. The edge emitter provides the greatest radiation power density which is important to any system requiring a narrow-beam configuration.

Laser Characteristics, General

Basically, the injection laser is an emitter with greatly modified construction. A laser operates similarly to an incoherent emitter when operated at low forward currents. However, if it is pulsed beyond a threshold current, lasing occurs and a marked increase in radiant power is produced; see Fig. 2. The increase is usually 1,000 times. The required current density to produce lasing can be between 10,000 to 20,000 A/cm^2—the operating current density is typically 50,000 A/cm^2.

Sustained application of these current densities would cause a very rapid rise in junction temperature, quenching of the lasing action, and eventual destruction of the diode. Therefore, lasers must be operated only in pulse service and within the specified maximum pulse durations and duty factors. Lasers can be operated from commercially available special pulsers or from easily-built SCR pulsers. Care is needed to prevent exceeding the reverse voltage rating of the laser.

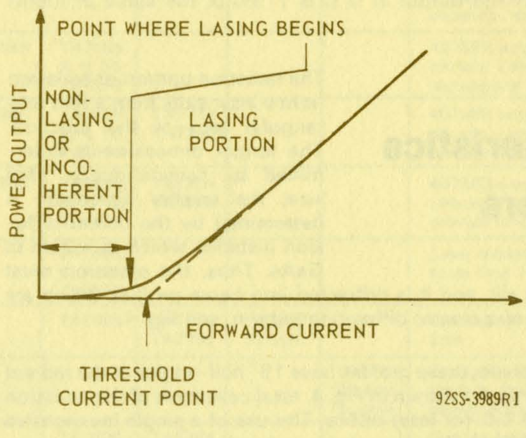


Fig. 2 Power output vs. forward current for a typical semiconductor laser diode.

Laser Characteristics at Cryogenic Temperatures

The threshold current, at which lasing will commence, is quite temperature dependent. At the cryogenic temperature of 77°K, the threshold current is only 1/10 that of the room-temperature value. This, in turn, changes the operating characteristics of the laser drastically. Table IV illustrates the differences in cryogenic and room-temperature operation of a typical laser.

At cryogenic temperatures, the wavelength shifts to 8450 Å (from 9050 Å) and matches the available S-25 image tubes.

The greater duty factor (2 vs 0.1) greatly increases the average power output. The efficiency is also much greater (40 vs 4%). The operating currents are usually generated by transistor pulsers (the pulses can be quite square).

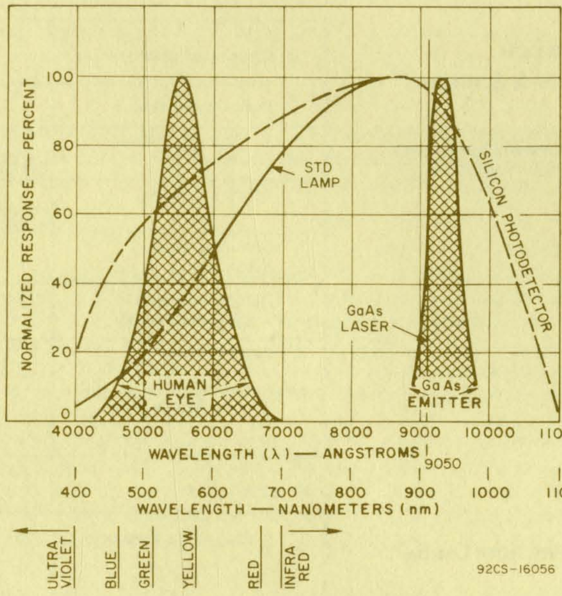


Fig. 3 Typical response of IR laser, IR emitter, human eye, silicon photodetector, and a standard lamp.

Table IV
Comparison of Laser Performance at Cryogenic & Room Temperatures

	Cryogenic Temp. (77°K)	Room Temp. (27°C)
Driving Current	4 A	25 A
Threshold Current	0.7 A	7 A
Radiant Power Output (Peak)	2.5 W	6 W
Pulse Duration	2 μs	0.2 μs
Duty Factor	2 %	0.1 %
Power Efficiency	40 %	4 %
Driving Voltage	1.6 V	9 V
Wavelength	8450 Å	9050 Å

Laser Operation at Room Temperature

The laser's characteristics at room temperature and in the industrial environment (0 to 70°C) is dominated by the threshold current. At temperatures above 25°C, the threshold rises, and with constant-current drive, the output power falls. The lower threshold of the new Close-Confinement* ("CC") lasers helps maintain the output at 40% (of the value at room temperature) at 70°C. At temperatures below 25°C, the threshold falls and the drive current must be reduced proportionately. The output at 0°C is 119% of the value at room-temperature.

Optical Characteristics of Lasers

The radiation pattern of emission from a laser exits from a thin rectangular area at the junction. The longer dimension is determined by semiconductor chip size; the smaller dimension is determined by the carrier-diffusion distance which is ≈2μm in GaAs. Thus, the emission must pass through a slit, and it is diffracted into beam profiles which are typically those of a classic diffraction pattern; see Fig. 4.

For gallium arsenide, these profiles have 15° half-angles at the radiant half-power points. As shown in Fig. 4, total collection of the emission requires f/# of 1.0 (or less) optics. The use of a single inexpensive lens can reduce these beam angles to a fraction of a degree.

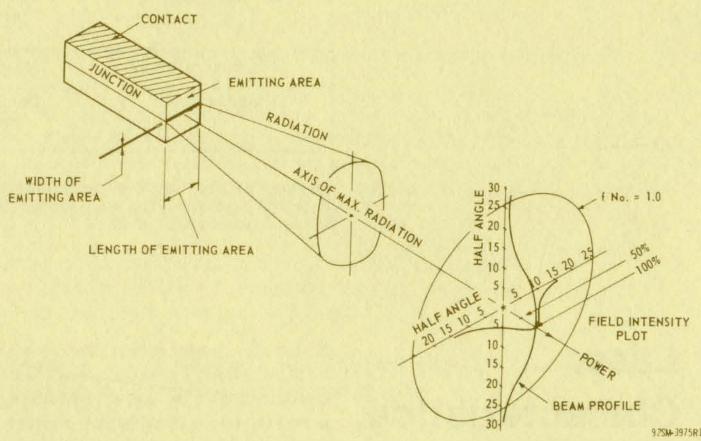


Fig. 4 Laser emission and emitting-area dimensions.

Lasing narrows the wavelength spectrum of the emission; see Fig. 3. The output wavelength for an injection-laser diode is determined by the spectrum of the gain function and by the cavity dimensions. The cavity, which is 3×10^{-2}cm or approximately 330 wavelengths long, breaks the spectrum into several narrow lines. The number of lines increases proportionately to the operating current above the threshold level; there are approximately 10 dominant lines at maximum output. The gain-function spectrum is determined by the semiconductor band-gap and the type of dopants. The band-gap, and therefore the spectrum, is temperature sensitive, about 2½ Å/°C. During the operating pulse, the junction temperature rises, resulting in a shift in the wavelength.

*See pg. 8

Applications

Applications for lasers and emitters may be divided into two categories. The first is called signalling. A large number of specific applications fall into this category. In all signalling applications, the radiation travels between the source and a detector. The detector indicates either the presence or the absence of a signal. The useful information derived from such a system is that the radiation path is either clear or blocked by some obstacle. In specific applications, the obstacle could be an unpunched hole in a card, or paper tape, or some opaque surface, or perhaps an intruder. The detector can also provide information regarding modulation or pulse-repetition rate of the source.

All such systems require only a high peak power although for simplicity, many are run CW.

Some advantages of lasers and emitters for signalling applications are:

1. Lasers can provide high peak power output.

2. Failure due to vibration and shock is not a problem for laser and emitters.

3. Lasers and emitters have fast rise times and are easily discerned from ambient illumination.

4. Laser radiation can be easily shaped into narrow beams.

5. Lasers and also emitters have narrow spectrums which allows the use of narrow-band filters at the detector to reject much of the ambient light.

6. Lasers and emitters are compatible with the best photo detectors such as silicon photo diodes and S1 multiplier photo tubes.

The second category is called illumination. In an illumination application, radiation is reflected off a target and an image of the target is formed at the receiver. In illumination applications, average power is most important.

Laser and emitters are useful in certain illumination applications because they can be pulsed. Pulsed light sources together with gated viewing systems can be used to see through smoke and fog. Other advantages of lasers and emitters are:

1. Lasers have great intensity and adequate average power.

2. Lasers and emitters have small emitting areas and their radiations are easily concentrated into narrow beams.

3. Radiation from GaAs lasers and emitters are invisible but they are readily detectable by image-converter tubes and night-vision TV systems.

Optics & Range

In general, the function of the transmitter optics is to direct, as effectively as practicable, the radiation to where the detector is or might be. Every possible position where the detector may be located must be adequately illuminated. The more area covered by possible locations, the greater the required total transmitted power. Thus, a compromise exists between transmitted power, and detector alignment accuracy. In most cases, the practical limits on alignment of receiver and transmitter set the practical limit on system's range.

Other possible limitations to the operating range are in the size and therefore the effectiveness of the optics, the atmospheric losses, and finally the problem of acquisition.

Application Selection Chart

	Optics	Application	MOD. or CW	Room Temperature Devices				Cryo-genic Laser Array	Notes
				Emitter	Laser Diode	Laser Diode Stack	Laser Array		
Signaling Applications		Paper Tape Reader	CW	40736R					40736R features necessary small size and high output
		Card Reader	CW	40736R					40736R can provide 1 mW (min.) output
		Shaft Encoder	CW	40736R					40736R for small size
	None	Keyboard	CW or CODED	40736R					40736R features small size and high output
		Circuit Isolator Coupler – "DC Transformer"	MOD	40736R					40736R has high output and modulation capability above 1 MHz
	Fiber Optics	Data Transmission	MOD	40736R					40736R features high output and modulation capability above 1 MHz
		Line Finder/ Edge Sensor	CW or PULSE	40736R	TA7606, 8, 9, 10, TA7699				40736R employs simple circuits. Laser diodes have rectangular beams
		Intrusion Alarm	MOD or PULSE	40736R	TA7606, 8, 9, 10, TA7699	TA7764 TA7765			40736R employs simple circuits. Laser diodes provide longer range
	Single Lens	Remote Control Signalling	MOD	40736R	TA7606, 8, 9, 10, TA7699	TA7764 TA7765			40736R employs simple circuits. Laser diodes provide longer range.
		Voice Communications	PULSE		TA7606, 8, 9, 10, TA7699				Laser diodes can operate at more than 10 kHz
		Ranging	PULSE		TA7699	TA7764 TA7765	TA7687-92 incl.		Laser diodes have fast rise time
Illumination Systems		Illuminator for Gated Viewers	PULSE					TA7789, 90 and custom	Cryogenic laser arrays produce the highest average power output
	Single Lens	Target Designator	PULSE or CW		TA7606, 8, 9, 10, TA7699	TA7764 TA7765			GaAlAs emitters operated CW match the type S-25 detector. Laser diodes produce small beams with simple lens.

Room-Temperature Devices

Emitters

OP-1
Approx. 2x Actual Size

OP-10
Approx. 2X Actual Size

Common Characteristics:

- Efficiency ≈ 2%
- Wavelength = 9,300 Å
- Edge emitters and parabolic reflector
- Small Package permits 0.1-in. mounting centers

Types (Standard)	Pkg.	Power Output* (mW) Min.	Power Output* (mW) Typ.	at I_{FM}▲ (mA)	Peak Power Output (mW) Typ.	at I_{FM} (A)	Case Polarity
40598A	OP-1	1.0	1.6	50	24	1.0	pos.
40736R, TA7437R	OP-10						neg.
TA7762R●	OP-10		2.5	40			neg.

* Total radiant
▲ Forward current
● Available 3rd Qtr., 1970

Shaded areas indicate data on types to be announced.

Single-Diode Lasers
(Close-Confinement Types)

OP-3
Approx. 2x Actual Size

OP-12
Approx. Actual Size

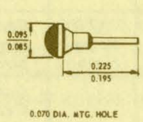
Common Characteristics:

- Efficiency ≈ 4%
- Wavelength = 9050 Å
- V_f at maximum drive is typically 9V
- Case polarity: Negative except for "R" version
- Pulse duration = 0.2 μs (max.)†

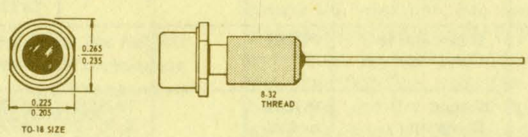
Types Standard	Types Special Order	Pkg.	Power Output* (W) Min.	Power Output* (W) Typ.	at I_{FM}▲ (A)	Source Size (mil)	Duty Factor (%) Max.	Threshold Current (I_{th}) (A) Typ.
TA7606	TA7606R	OP-3	1	2	10	3 x 0.08	0.1	4
TA7608	TA7608R	OP-3	5	6	25	6 x 0.08	0.1	7
TA7609	TA7609R	OP-3	10	13	30	9 x 0.08	0.1	9
TA7610	TA7610R	OP-3	10	13	40	9 x 0.08	0.1	10
TA7699, R		OP-3	15	23	75	16 x 0.08	0.02	20
TA7864			25		75	24 x 0.08		
TA7763■			25		100	24 x 0.08		
TA7705■		OP-12	40	50	250	55 x 0.08	0.005	75
TA7787■		OP-12	60	65	250	55 x 0.08	0.005	75

* Total radiant, peak
■ Available 2nd Qtr., 1970
† Except 0.1 μs max. for TA7705 and TA7787
▲ Forward current, peak

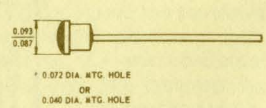
Packages



OP-1



OP-3



OP-10

Laser Arrays
[Close-Confinement Types]

OP-4A
Approx. Actual Size

Common Characteristics:
- Pulse duration = 0.2 μs (max.)
- Wavelength = 9050 Å
- Duty Factor = 0.02%
- Series wired
- Drive current = 25 A
- Case polarity: Negative except for "R" version

Types		No. of Diodes	Power Output* (W)		at I_{FM}▲ (A)	Source Size (Typical) (mil)
Standard	Special Order		Min.	Typ.		
TA7687	TA7687R	10	25	50	25	100 x 0.08
TA7688	TA7688R	15	35	75	25	150 x 0.08
TA7689	TA7689R	20	50	100	25	110 x 40
TA7690	TA7690R	30	75	150	25	160 x 40
TA7691	TA7691R	40	100	200	25	110 x 60
TA7692	TA7692R	60	150	300	25	160 x 60

* Total radiant, peak
▲ Forward current, peak

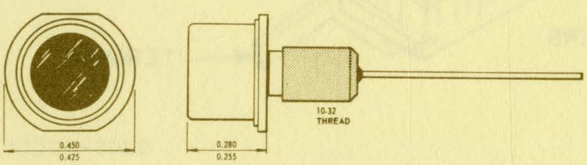
Laser Stacks
[Close-Confinement Types]

OP-12
Approx. Actual Size

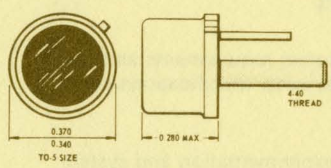
Common Characteristics:
- Wavelength = 9050 Å
- Series wired
- Pulse duration = 0.2 μs (max.)

Types	No. of Diodes	Power Output* (W)		at I_{FM}▲ (A)	Source Size (mil)	Duty Factor %
		Min.	Typ.			Max.
TA7764△	3	25	30	40	10 x 10	0.01
TA7765■	2	50			25 x 4	

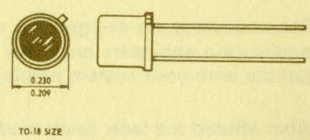
* Total radiant, peak
▲ Forward current, peak
△ Available 2nd Qtr., 1970
■ Available 4th Qtr., 1970



OP-12



OP-4A



OP-2

Room-Temperature Devices (Cont'd)

Close Confinement ("CC") GaAs Lasers

RCA injection lasers feature the "Close-Confinement" structure which provides high efficiency at room temperature. Prior to the announcement by RCA of "CC" lasers, injection lasers had limited practical use due to high drive currents, limited power output, and temperature limitations.

CC-process lasers permit a broader range of power output at practical drive currents and pulse rates. The CC process confines the radiation generated in the junction to the junction area thus greatly reducing the absorption in the adjacent crystal structure. While the internal quantum efficiency of the device remains the same, more of the generated radiation is emitted resulting in a substantial increase in external quantum efficiency. In general, the radiated output of the CC laser crystal is double that from non-CC types and the threshold currents are halved.

Other benefits include the following:

1. Uniform light radiation across the emitting junction—there is less possibility that dark or bright spots will occur on the laser face.
2. Higher temperature operation—CC lasers can be supplied for performance at temperatures as high as 70°C.
3. Extended performance at high repetition rates—with adequate heat sinking, repetition rates as high as 20 kHz have been achieved within the rated duty factor.
4. Improved reliability—since device current density has been substantially reduced through the CC process, improved reliability can be projected.

All of the laser diodes and laser arrays listed in this brochure are CC types.

Replacement Chart

Types		Difference (New vs. Old)
Old	New	
TA7008	40598A	300% more power output
TA2628, R	TA7606, R	Same output at ⅓ input
TA2930	TA7692	300% more power output
TA7438	TA7687	250% more power output
TA7526	TA7608	OP-3 pkg. instead of OP-2
TA7527	TA7608	OP-3 pkg. instead of OP-2
TA7535	TA7606	OP-3 pkg. instead of OP-2
TA7559, R	TA7699, R	OP-3 pkg. instead of OP-2
TA7594	TA7610	OP-3 pkg. instead of OP-2
40598	40598A	300% more power output

Custom Arrays

Cryogenic Laser Arrays

RCA Optical Products has a proven production capability for the manufacture of laser arrays having high average power. These devices feature very compact source areas, low drive currents, and high efficiency. They are constructed on heat sinks suitable for cold-head mounting. Light integrators and means for incorporating optical shrouds, etc. can also be provided.

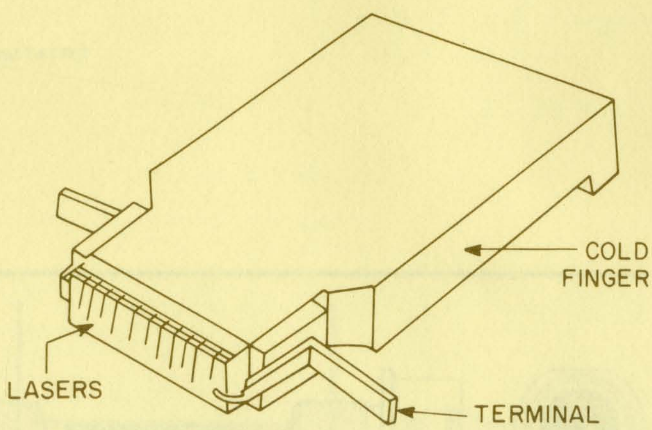
Typical range of performance at 77°K is as follows:

Power Output (Av.): 1 Watt to 50 Watts

Power Conversion Efficiency: 15% to 40%

These devices are designed to meet customer requirements and our application engineers are ready to help develop specifications compatible with your system needs.

Also offered are laser array modules for experimentation and system development. These are individual array strips mounted on a cold finger as shown below.



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Custom Arrays [Cont'd]

These modules are suitable for stacking into various assembly configurations. Two basic modules are offered as follows:

Table V

Module Type	No. of Diodes (Typical)	Active Length (In.)	Av. Power Output (W) at 77°K
		Max.	Min.
TA7789	15	0.25	0.5
TA7790	30	0.5	1.0

Other parameters:

Drive Current	4 to 6 A (peak)
Rep. Rate	10 kHz
Duty Factor	2% Max.
Efficiency	20% (min.) – at values of power output specified in above table

Table VI Possible Configurations of Modules for Various Levels of Power Output

No. of Pairs of Modules	TA7789		TA7790		TA7789 and TA7790		2 TA7790's	
	P_0 (AV) (W) Min.	Emitting Area (In.) Typ.	P_0 (AV) (W) Min.	Emitting Area (In.) Typ.	P_0 (AV) (W) Min.	Emitting Area (In.) Typ.	P_0 (AV) (W) Min.	Emitting Area (mil) Typ.
1	1.0	0.03 x 0.3	2.0	0.03 x 0.5	3.0	0.03 x 0.9	4	0.03 x 1.1
2	2.0	0.09 x 0.3	4.0	0.09 x 0.5	6.0	0.09 x 0.9	8	0.09 x 1.1
3	3.0	0.15 x 0.3	6.0	0.15 x 0.5	9.0	0.15 x 0.9	12	0.15 x 1.1
4	4.0	0.21 x 0.3	8.0	0.21 x 0.5	12.0	0.21 x 0.9	16	0.21 x 1.1
5	5.0	0.27 x 0.3	10.0	0.27 x 0.5	15.0	0.27 x 0.9	20	0.27 x 1.1

Room-Temperature Arrays

In addition to the laser arrays defined as TA7687—92, custom arrays can be made available to customer specifications. Variations which can be provided are as follows:

- Power Output (Peak): to 1 kW
- Variations in source area and aspect ratio
- Reverse-polarity devices
- Packaging
- High-density arrays (via stacking)
- 8500 Å wavelength (GaAlAs)

Contact RCA's Marketing or Application Engineering activity for assistance in specifying these devices to comply with your application requirements.

Terms & Definitions

***Light** – For the devices described in this brochure, "light" refers to radiation that is not necessarily visible. This radiation may be analyzed and controlled by optical techniques.

***Lasing** – The process of stimulating early recombination of carriers to emit radiation in the same direction as, and coherent with, some initial (stimulating) radiation. It represents amplification which preserves the direction, frequency, and phase of the amplified light.

***Laser** – (**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation) – A device for generating light by lasing (as explained above). Although a certain degree of coherence is obtained in the output radiation of a semiconductor laser, neither absolute coherence or collimation of the output beam is a necessary result of lasing.

***Injection Laser Diode** – A semiconductor p-n junction which uses lasing to increase the light output and concentrate the light in a small area. The initial radiation which is amplified by lasing comes from spontaneous (non-coherent) emissions precisely like those of an emitter. The amplification is in excess of 1,000 times. The amplification occurs only in the junction area where carriers are able to recombine and between the faces of a Fabry-Perot cavity formed by two parallel sides of the semiconductor chip. Thus, the amplified radiation is concentrated into a small area. The radiation leaves the cavity through the partially transmitting side of the semiconductor chip.

***Threshold Current** (of a single-diode laser) – That current which produces zero power output on the best straight-line fit for the lasing portion of the laser power output-vs.-current curve; see Fig. 2.

***Threshold Current** (of a laser array) – The current where lasing begins and above which the power output of an injection laser diode rises nearly linearly. In an array, there will be differences in the threshold currents among the diodes. The threshold of the array is the threshold of the diode with the lowest threshold current. Above this value of current, other diodes will begin lasing with the result that the linear power output-vs.-current relationship is modified from that of Fig. 2.

***Emitter** – A very general term for any device from which radiation is given off. Specifically, this brochure uses the term to refer to semiconductor diodes which emit radiation when forward biased and do **not** lase.

***Duty Factor** – The proportion of time spent operating; i.e., frequency x pulse width.

Close Confinement – See page 8.

Emitting Area – Area measured by a microscopic scan across the emitting surface very close to the emitting surface (near-field pattern) and defined by the half-power points. For an injection-laser diode, the emitting area is a function of the semiconductor chip size and carrier diffusion length.

Emitting Area of a Laser Array is defined by the rectangle whose area encloses all the laser diodes making up the array.

Spectrum – Band of wavelengths produced by the laser or emitter. Spectral width is usually defined between half-amplitude points.

Radiation – A very general term to describe all electro-magnetic waves. It includes heat (14,000 to 40,000 Å), visible light (4,000 to 7,000 Å), infrared light, and x-rays (< 30 Å).

Pulse Width – The pulse duration at half amplitude points.

Irradiance – Radiant power per unit area incident upon a surface – power density incident.

Emittance – Radiant power per unit area emitted from a surface – power density radiated.

Beam Half-Angles – The angles at the half-power points on a small-aperture scan of the emitted beam at a considerable distance (far field) from the laser. In an injection laser, these angles originate primarily from defraction of the radiation at the emitting area.

Coherence (phase, spatial, and polarization) – Absolute term which implies that there is no variation in phase, amplitude or polarization at the wavefront. Lasers, as a class of light source, come closest to absolute coherence in comparison to other classes of light sources. In comparison with gas lasers, injection lasers have rather poor coherence (due to their low-Q cavity and broad-gain function spectrum).

***Non-Coherent** (or incoherent) – Refers to radiation without coherence . . . usually completely random in phase and direction.

***Power Output** – Total emission from a device without regard to direction or wavelength.

Efficiency:

Differential Efficiency – Slope of power vs. current curve measured above threshold for a laser, usually in watts/ampere.

Emission Efficiency – Number of photons emitted per number of photons generated.

External Quantum Efficiency – Number of photons emitted per number of carriers recombining.

Power Efficiency – Power radiated per power input.

Quantum Efficiency – Number of photons generated per number of recombining carriers.

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*This definition is unique to this brochure.

Efficiency \ Device	Emitter (Room Temp.)	Laser (Room Temp.)	Laser (Cryogenic)	Units
Quantum	90	80	80	%
Ext. Quantum	2.4	24	42	%
Differential	0.032	0.43	0.6	W/A
Emission	2.7	30	53	%
Power	2.3	3.6	40	%

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3. "High-Speed Recording on Infrared Film with GaAs Light Emitting Diodes," M. Green (Navy Underwater Sound Lab.), AD 664-654, Defense Documentation Center, Defense Supply Agency, U.S. Department of Commerce, Nov. 1967.

4. "Semiconductor-Diode Light Sources," M. R. Lorenz and M. H. Pilkuhn, IEEE Spectrum, April 1967.

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1. "Improved Red and Infrared Light-Emitting AlxGal-xAs Laser Diodes Using the Close-Confinement Structure," H. Kressel and H. Nelson, Appl. Phys. Letters, Vol. *15*, No. 1, July 1969.

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3. "Physical Basis of Non-Catastrophic Degradation in GaAs Injection Lasers," H. Kressel and N. E. Byer, Proceedings of IEEE, Jan. 1969.

4. "Laser Technology and Applications," "Semiconductor Diode Lasers," – Chapter 5, H. T. Minden, McGraw-Hill, Inc.,1968.

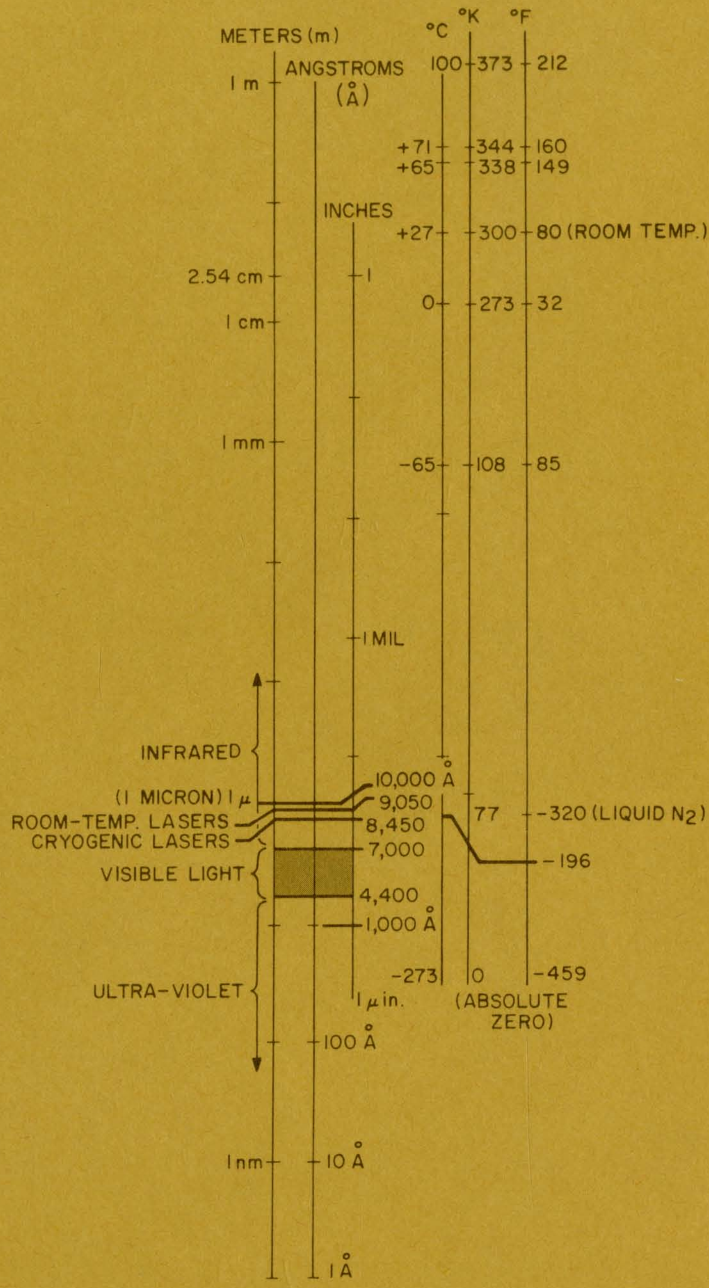
5. "RCA Electro-Optics Handbook," General information plus analysis of Laser Range Finder, page 13-5, RCA Defense Electronics Products, Aerospace Systems Division, Burlington, Mass., SCN 102-67, 1968.

6. "High Power Pulsed GaAs Laser Diodes Operating at Room Temperature," H. Nelson, Proceedings of IEEE, Aug. 1967.

7. "Applied Lasers," James Vollmer, IEEE Spectrum, June 1967.

8. "GaAs Injection Laser Radar," B. S. Goldstein and G. F. Dalrymple, Proceedings of IEEE, Feb. 1967.

9. "Handbook of Military Infrared Technology 1965" (extensive information on infrared systems and components including reflectivity data, detector characteristics, and cooling systems) – Superintendent of Documents, U.S. Government Printing Office.



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