PERIPHERAL VISION DISPLAYS - THE FUTURE

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GML has been active in research studies on future developments for the PVD, and I would like to outline several areas which have progressed to the developmental stage.

1. Fibre Optics

We believe the fibre optics problem of recollimating the light as it leaves the fibre has now been solved. Development engineering has begun on an alternate configuration to the present baseline system.

The availability of a means of placing the laser and power supply in a remote location opens up many new possibilities:

(a) The projector will be considerably smaller and more compatible with small or high density cockpits.

(b) The extra degrees of freedom in laser size opens up the possibility of using a source other than the HeNe red line.

Which brings us to the second item:

2. Change of Display Colour

It has been known for some time that the red HeNe display is not the optimum colour for PVD, but it does have the advantages of being inexpensive, reliable and available.

The disadvantages of red, to mention just two at this stage, are:

(a) Red signifies danger.

(b) Red light striking a red enunciator light will give a momentary red flash to the pilot, which adds stress to his flying.

In order to choose the optimum colour for display, we undertook a research program to measure retinal sensitivity against varying ambient conditions for three different colours:

Red	-	HeNe laser	-	632 nm
Green	-	Argon Ion laser	-	514 nm
Blue	-	HeCd laser	-	442 nm

The reasons why these colours were chosen, were fairly straightforward. They gave (theoretically) wavelengths which represented either highs or lows of retinal sensitivity for both Foveal and Peripheral Vision, and they were readily available. (See Figure 1).

The experiments used 8 subjects, and each were seated 1 metre from a screen on which was displayed a gently undulating line. Ambient lighting was varied from maximum (600 lux using a bank of photoflood lamps) to minimum (dark and scotopic with 10 - 15 minutes dark adaptation time). For each measurement, the light was attenuated (using Wratten neutral density filters) until the subject declared that the line was just visible as a PVD, and also when the line was just perceptible.

The results are shown in Figure 2.

Figure 3 illustrates the theoretical predictions along with the measured values. The prime conclusion is that a Green laser gives about 3 times improvement in retinal sensitivity for photopic vision. Or put another way, the existing 3 mW HeNe red line could be replaced by a 1 mW green line and compete with the same ambient conditions.

Unfortunately, the large increase in retinal sensitivity under scotopic conditions cannot be used, as we are already well-dimmed for dark adaptation.

The next stage was to find a suitable green source which satisfied the requirements of size, weight, power consumption, cost, etc.

Analysis of the Lagrange Invariant for optical systems, which briefly, states that in any closed optical system, the product of image size x angle of field x refractive index of medium, is invariant whenever a ray path crosses the optical axis, suggests that only a laser can supply the small image, narrow angle display we require.

A survey of all possible green (or yellow) laser sources, gave many possibilities, most of which can be disregarded due to size, weight, power consumption and cost.

The "short list" of options which we are pursuing is shown in Figure 4.

One conclusion which becomes very clear on looking at our options, is that the HeNe red line stands in a class of its own, at least with regard to power consumption and cost. With regard to weight and size, we have received encouraging news from our suppliers with respect to future requirements, but the HeNe laser is by far the most efficient laser ever produced.

The next question which arises, is how bright we can make the display, in order to compete with the Mil. Spec. requirement of 10,000 ft. candles (107,000 lux).

Extrapolation of the curves of Figure 2 gives approximate power requirements for threshold detection for each colour. I stress "approximate", as we are extrapolating over nearly 3 orders of magnitude to reach 10,000 ft. candles.

HeNe red line	70 mW
Argon green line	20 mW
HeCd blue line	150 mW

A few words about the HeCd laser. The laser used was a "positive column" laser, where photons could not be excited to energetic levels beyond the blue line. We are also negotiating with two possible suppliers to acquire a "hollow cathode" HeCd laser, where we may excite our photons to produce blue, green and red lines. In fact, we may soon be in a position to offer a "white" light laser.

The continued use of lasers leads us into our next topic.

3. Holography

We are already experiencing some problems related to projecting our bar of light on the changing contours of modern-day instrument panels. In addition, small instrument panels preclude the possibility of using a true peripheral display. We cannot display the line on the windscreen, as this could present an easily recognisable signature to the enemy.

Holography offers the possibility of giving the pilot a horizon bar in space, either inside or outside the cockpit. It enables us to wind the horizon around him, so giving true peripheral vision. It also allows us to forget the concept of a horizon "line", and present to the pilot a view similar, if not identical to the true horizon; i.e. an interface between two areas, sky or ground, blue or brown, or even to present the complete 3 D picture of an airport runway, regardless of whether the airport is in fact visible.

We are still in the very early stages of the holographic PVD, but the potential of this technique is extremely impressive and stimulating even at this early stage.

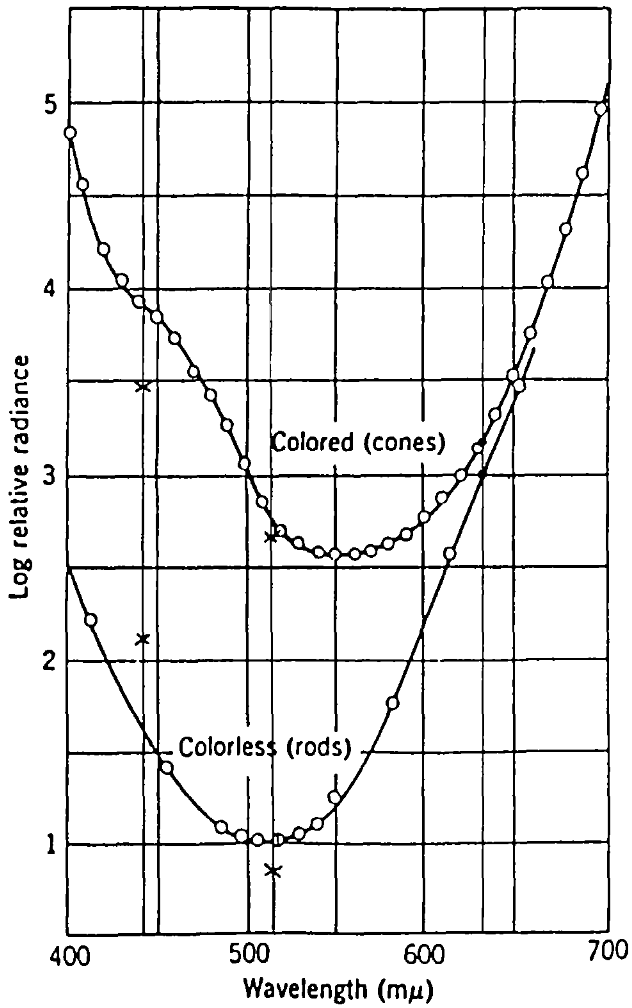

FIG. 1. Relative radiance required for rod and cone vision at different wavelengths. Positioning of the two curves is based on the fact that the thresholds for rods and cones are most similar in the red beyond about 625 mμ. The precise form of the curve and the values of radiance required for the rods will depend upon the duration of exposure, the area of stimulus, and its retinal position. The same considerations apply to the curve for the cones. In consequence, the precise relationship of one curve to another will depend upon the values of these parameters. The curves shown here may be considered to apply to conditions that give minimum thresholds for each type of receptor. (From Hecht and Hsia, 1945.)

•	Reference	632 nm
×	Measured	514 nm
×	Measured	442 nm

Figure 1

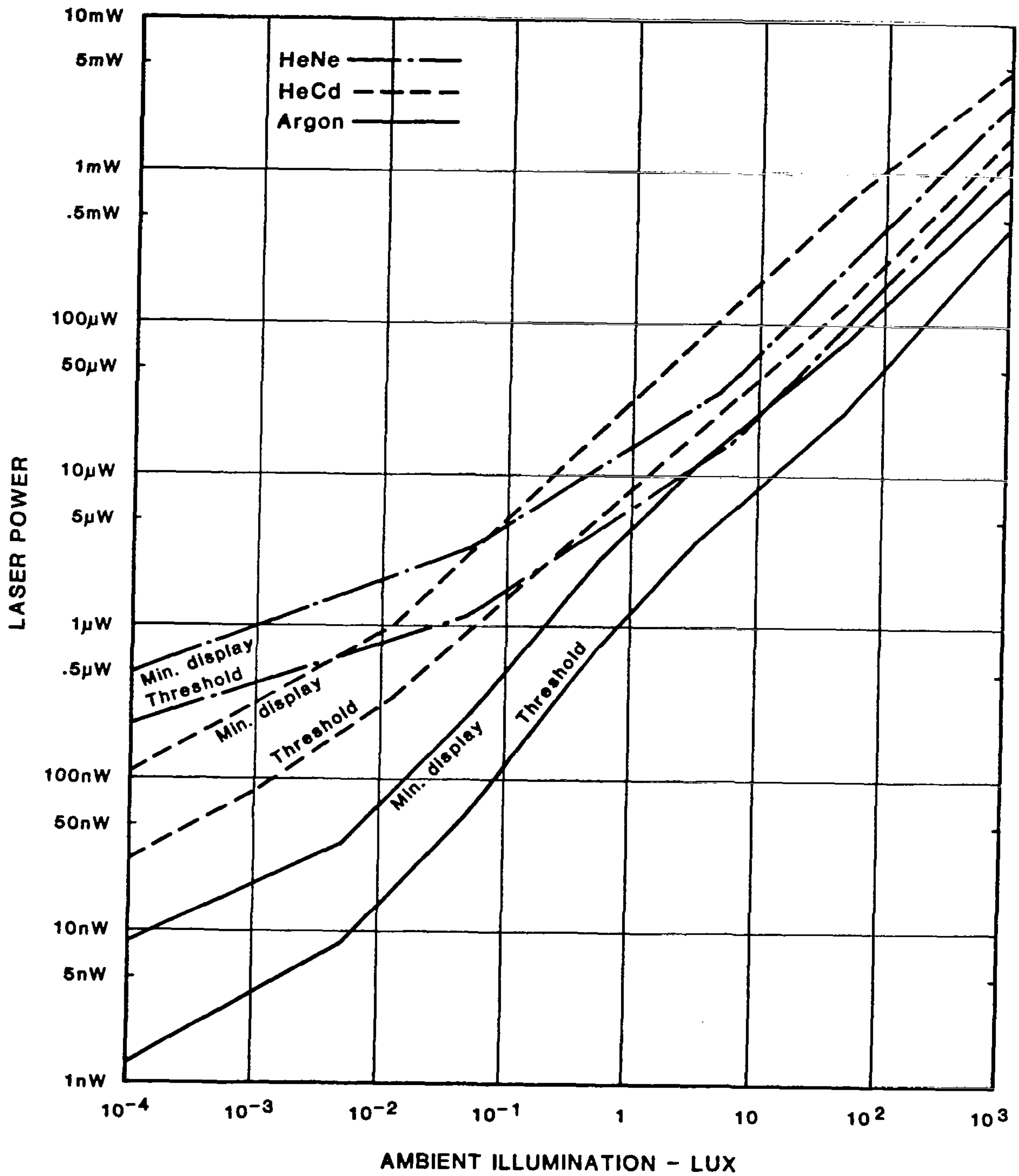

Figure 2 RETINAL SENSITIVITY

Relative Retinal Sensitivity

			Calculated		Measured	
			Foveal	Peripheral	Foveal	Peripheral
HeNe	Red	632 nm	1	1	1	1
Argon	Green	514 nm	2.5	100	3.1	160
HeCd	Blue	442 nm	0.2	22	0.48	7.4

Figure 3

Laser Source for Green Light (530 nm)

	Gas Lasers			Solid State Lasers	
	He Cd		Argon ion	Nd YAG + SHG	
	Pos. Column	Hollow Cath.		Tungsten Halogen Pump	High Density LED Pump
Output power mW	20	20	25	10	50
Wavelength nm	442 but fluorescent screen possible	530	514	532	532
Input power W	300	200	350	200 ?	200
Size (inc. P.S.)	6" x 6" x 12"	6" x 6" x 12"	6" x 6" x 12" could be developed	8" x 6" x 5"	6½" x 2½" x 1¼"
Weight (inc. P.S.)	10 - 15 lbs.	8 - 12 lbs.	20 lbs.	7 lbs.	5 lbs.
Cost (inc. P.S.)	$5,000	$5,000	$6,000	$5,000	< $5,000
Cooling	Air convection	Air convection	Air convection	liquid & air	air convection
Mil. Spec.	Yes ?	Yes ?	Yes ?	Yes	Yes
Risk ≡ Development	Low	High	High	Low	High
Comments	Available in near future if fluorescent screen acceptable	Not yet available to these sizes and weights	Not yet available	Available within 6 months	Not yet available. Involves some R&D investment

Figure 4