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Comparison of the Forensic Light Sources; Polilight, Luma Light and Spectrum 9000.

Prepared by

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SUMMARY

The Polilight, Luma-Lite and Spectrum 9000 are comparable forensic light sources currently available within North America. This paper presents measurements of the spectral transmission and power output through the various filters of these light sources. In addition, a circle of light produced by each source has been photographed to illustrate the uniformity of the beam.

RÉSUMÉ

Polilight, Luma-Lite et Spectrum 9000 sont des sources lumineuses comparables, actuellement employées dans le domaine judiciaire en Amérique du Nord. Dans le présent document, on donne des mesures de la transmission spectrale et de la puissance obtenues avec les divers filtres de ces sources lumineuses. Une photographie du cercle de lumière produit par chacune de ces sources a aussi 6t~ incluse pour illustrer l'uniformité du faisceau.

A Comparison of the Forensic Light Sources;
Polilight, Luma-Lite and Spectrum 9000

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Introduction

Forensic light sources have been used for many years as an aid to crime scene examination. They can facilitate the discovery of hair, fibre and biological stains at the scene as well as allow Identification personnel to utilize the arsenal of fluorescent chemicals currently available for detecting fingerprints [1]. Forensic light sources were originally designed to be a cheaper alternative to the Argon ion laser and consequently they are sometimes referred to as Alternate Light Sources.

There are three main suppliers of forensic light sources in North America: ODV (Polilight), Payton (Luma-Lite) and Omnichrome (Spectrum 9000). The lights cost from ten to twenty thousand dollars (US). Other sources are available in Europe.

All forensic light sources operate according to the same principle. They contain a high powered lamp which generates white light within a reflector. The light passes through a small aperture and is then focused through a lens to produce a circle of light. Barrier filters are positioned in front of the beam to block all but the desired wavelengths. The ability of the forensic light source to produce a good quality beam is dependent upon the lamp bulb, the optics and the quality of the filters chosen by the manufacturer.

An earlier study compared the filters and power output of the Luma-Lite to the Omniprint 1000, an earlier Omnichrome model [2]. Several papers report on the ability of the various light sources in detecting biological samples [3-5].

We have conducted a study in which three of the sources, Polilight; Luma-Lite; and Spectrum 9000 (the new generation Omnichrome light), have been compared. The light source comparison involves several factors: the range of wavelengths available through the choice of filters; the total power output passing through each filter; the quality of filter blocking outside the wavelength range; the uniformity of the beam; and the ease of use.

METHODS

Lamps

The Polilight and the Spectrum 9000 both use a 300 watt Xenon arc lamp. The spectral output of this lamp includes a substantial amount of ultraviolet (UV) light and is almost level across the visible range (see Figure la). The lamp has an integral parabolic reflector which produces an intense, nearly parallel beam of about 20 mm diameter but which is not uniform across the beam. The beam can be focused into the end of an 8 mm diameter light guide. The power supply and lamp are expensive but the lamp lifetimes are of the order of 1000 hours.

The Luma-Lite uses a 350 watt Indium arc light which was originally designed for cinemagraphic projection. The light output spectrum of the arc has very little UV, rises slowly through the violet and is essentially linear above 450 nm (see Figure lb). The lamp has an integral reflector which focuses the strongly diverging beam uniformly across an 18 mm diameter aperture. It is this uniformity of the source that gives the Luma-Lite its uniform output beam. This beam cannot be focused into an 8 mm light guide even with strongly focusing lenses. Even the larger diameter fibre optic guide supplied with the Luma-Lite can only intercept a small proportion of the incident light, which significantly reduces the power output at the end of the guide compared with the direct beam. Although an efficient lamp, the lower initial cost is offset by a limited lifetime of 75-100 hours.

Optics

The way the light is directed, the arrangement of the lenses and the filters, all affect the proportion of light emitted by the lamp as well as the uniformity of the beam. The forensic light sources are all different in this respect.

Filters

It is particularly important that the barrier filter effectively blocks out any of the lamp's emission on the red side of the bandpass as this is where observed fluorescent emission will be occurring. Otherwise emitted light from the source that leaks through the filter will be reflected off the surface and swamp the light emitted from the fingerprint.

The blocking needed depends on the intensity of the fluorescence. For detection of latent prints by their natural fluorescence on low fluorescing surfaces it was estimated that 10'6 blocking was needed [6]. This simply means that only 0.0001% of the light can pass through the filter outside the bandpass wavelength range. Prints enhanced by an added fluorescent dye are stronger, consequently less blocking, perhaps of the order of 10'3 to 10-4, is sufficient. Generally 0.1% blocking is considered sufficient for chemically treated fluorescent fingerprints. That is, if only 0.1% of the lamp’s output, at the wavelengths at which the fluorescing dye is being observed, is allowed through the filter, most fingerprints will still be seen.

To properly observe fluorescent fingerprints, viewing filters are placed over the eyes (goggles) and camera. The viewing filter blocks out the reflected light from the source as well as any fluorescence that may have been stimulated in the background surface, providing it does not coincide with wavelengths passed by the filter. A good rule of thumb is that the 0.1% cut-on wavelength of the viewing filter should be to the red side (higher wavelength) of the 0.1% cut-off wavelength of the lamp filter. A dye that has a small Stokes shift (the difference between the peak excitation and the peak emission wavelengths) will make it very difficult to find filters for the lamp and for viewing that will not overlap in wavelength and still allow the maximum signal to be recorded.

Tuning

The ability to continuously vary the excitation peak wavelength is known as tuning. It is of value where a weak fluorescent print is found on a fluorescent background. Since it is unlikely that the excitation spectrum of the background and the print are identical it may be possible to find wavelengths where the difference between the two is at a maximum thus increasing contrast. A DFO treated print on a fluorescent paper background is a prime example. Since DFO has an exceptionally wide excitation spectrum [7] the excitation wavelength can be varied to find a region in which the background is reduced while the print continues to fluoresce. The absolute brightness of a print is reduced by this procedure because the power in the source is reduced by the tuning and the excitation wavelength chosen may not be at the peak absorption of the fluorescent chemical.

It is also possible to tune the viewing filter and thus have a second chance to increase the contrast. This is possible no matter which source is used provided the viewing filter bandpass does not encroach on the excitation bandpass [8].

The light sources all use multi-layer interference filters. In the Luma-Lite and the Spectrum 9000 these filters are fixed vertically in front of the beam. In the Polilight they can be tilted which moves the point of maximum transmission towards shorter (blue) wavelengths. (Absorption type filters cannot be tuned). A second method of tuning is to use a monochromator where the light beam is dispersed by a reflective mirror with many ruled fine lines (grating). Since the grating angle can be continuously varied so can the peak output wavelength. The variable output port of the Spectrum 9000 uses the grating system to achieve tunability.

Modes of Operation

The three light sources being compared for this study can be operated in a variety of different ways. The Luma-Lite is perhaps the simplest since it is the direct beam, with a mirror angled at 45 degrees in a "snout", that is most often utilised for fingerprint detection. Changing wavelengths requires removal of one filter unit and replacing it with another. Use of the fibre optic guide necessitates the removal of the filter housing assembly and the installation of the guide assembly. In addition the fibre optic guide is only available for the blue filter (450 nm).

Usually the chosen mode of operation for the Polilight is with the liquid light guide attached to the output port. Filter changes can be accomplished without disconnecting the light guide, by turning a filter wheel. A separate fibre optic guide is supplied for the infrared output port.

For the Spectrum 9000 there are several different modes of operation since the light source contains a discrete mode (filter wheel arrangement of lenses) and a variable mode (grating monochromator for tuning). Both can be operated using the liquid light guide or the fibre optic guide. The filter wheel system is comparable to operation of the Luma-Lite and the Polilight which both utilise filters, whereas the grating system of the Spectrum 9000 is best compared to the Polilight only, since this also offers tunable light.

EXPERIMENTAL

Spectral Output

If the output of the lamps were uniform across the spectrum it would have been sufficient just to measure the filter transmission and assume the spectrum of the beam was the same. However as Figures la and lb show the white light output of the sources is far from uniform. It was therefore necessary to measure the true output spectrum.

We used the emission monochromator of an SLM 8000C spectrofiuorimeter to measure the spectral output of each filter. The beam of light was focused through a pinhole onto the input lens of a double monochromator coupled to a photon counter. The sensitivity of the photon counter allowed us to measure the power over a range of a few photons per second up to 50,000 photons per second. We were thus able to accurately measure output outside the bandpass to observe the quality of the blocking for each filter.

Power Measurement

The power output of the forensic light sources in all possible modes of operation was recorded using a Scientech 3610 power meter which has a linear response from the ultraviolet far into the infrared. The power meter measures the total power that falls onto a 2.5 cm diameter thermally sensitive surface that is positioned at the base of a 6.3 cm deep well. It measures power on scales as sensitive as I milliwatt (mW) up to 3 watts (W).

The power meter was positioned in front of the light beam at a distance which allowed the detector area to intersect a circle of light 5 cm in diameter, The total power output for the light source in this larger circle was four times the meter reading ([area of light source beam/area of detector]). The distance between light source and meter varied for each forensic light source and for each mode of operation (i.e. for the liquid light guide, the Spectrum 9000 was positioned 6.3 cm from the power meter surface, and for the fibre optic guide the Spectrum 9000 was 7 cm from the meter surface). The power meter was placed on a jack and the height adjusted until the head of the meter was in the centre of the beam.

There was a great deal of subjectivity in determining the 5 cm circle because of lack of uniformity in the beam. The beams delivered by the flexible guides presented the most problems (see Figures 2a-C). The liquid guide for the Polilight tended to have intensity in the centre falling off towards the edges. The liquid guide on the Spectrum 9000 and the fibre optic guide on the IR port of the Polilight produced very irregular patterns. In all cases where the areas of highest light intensity occurred in the centre of the beam the measurements on the power meter do not truly represent the average power over the whole circle but are more likely overestimates of the power available.

The power output was recorded after allowing the bulb to warm up for a 15 minute period. All three lamps produce infrared light which will be transmitted by some of the filters. Two power measurements are therefore required to correct for any infrared contribution to the power output. One measurement is the total output power through the filter. The second is with the visible light blocked by a filter which after correction gives the infrared contribution to the total power. The corrected power output in the visible is determined by deducting the infrared contribution from the total power.

Uniformity

Uniformity of the beam is important, when photographing a weak print, since the areas where the "hot spots" of light do not fall may be lost by the camera. Increasing the distance between the point of light output and the surface will produce a more uniform spread of light over the print but at the cost of reducing power since power is lost by the square of distance. The image of a 5 cm diameter circle of light formed by the beam intersecting with a piece of paper positioned vertically in front of the light source was photographed using automatic exposure (Figure 2).

RESULTS

Tables 1, 2 and 3 show the spectral bandwidths and total power output in each band for all the filter settings for each light source whilst in the usual mode of operation. Figures 4, 5 and 6 show the shape and relative power of the bands in diagrammatic form. Our power output values are about 75% of those claimed by the manufacturer (only quoted for the Polilight). This is probably due to different measurement configurations and should not be considered a significant discrepancy.

Ultraviolet

The Polilight produces 0.16 watts (W) of power in a 32 nm band centred at 356 nm (labelled 350 nm). The Spectrum 9000 ultraviolet band labelled 400 nm produces a 20 nm band centred at 400 nm with 1.24 W of power in a wavelength range that borders on the UV and visible. The Luma-Lite produces negligible power in the UV (0.08 W in a band centred at 365 nm) which is expected since there is very little UV generated by the source (see Figure lb).

Blue Light

These wavelengths are largely used for crime scene work and detection of biological fluids [4]. All these units use their broadest filters in order to increase power in this area. The Luma-Lite uses a very wide band filter (72 nm) that results in a lot of power in this band (12 W) with some in the near UV and violet. This is in contrast to the estimated power output of 850 mW quoted by Menzel [2]. The Spectrum 9000 uses a 60 nm band filter that produces almost 3 W at the end of the fibre optic light guide with some violet but no UV. This filter is labelled as 530 nm which would fall in the green but the peak occurs at 474 nm and only 0.1% of the light is transmitted at 530 nm. The Polilight produces a 56 nm band containing 0.56 W at the end of a 2 metre liquid guide.

Green/Yellow Light

This range is used for fluorescent dye excitation, principally the DFO-amino acid product which has a wide absorption band and also Rhodamine 6G whose maximum absorption peak is at 530 nm.

In this area the Polilight offers three filters with peaks at 530, 555 and 590 nm, the Luma-Lite has two filters at 530 and 570 nm, and the Spectrum 9000 has one filter at 570 nm. The Spectrum 9000 and the Luma-lite have the highest power output in the green of 0.8 W compared to an average of 0.4 W for the filters of the Polilight. All lamps appear to have sharp well blocked filters in this region.

Red and Infrared Light

The Polilight has two filters in the red at 620 and 650 nm which makes it the only light source to provide output in the red. Only the Polilight and the Spectrum 9000 have filters for the infrared. The Polilight allows infrared above 700 nm to pass (see Figure la) and has a total output power of 0.35 W. The Spectrum 9000 when used with the liquid light guide passes infrared above 676 nm and has an output power of 7.7 W.

There are very few dyes that fluoresce in the infrared so that this region is usually used for reflective examination of documents. For document examination a broad band source is needed along with a series of narrow band infrared camera filters (as supplied with the Polilight). Observation is made easier by use of modern video and CCD cameras which have good infrared sensitivity up to 1100 nm giving another 400 nm bandwidth in which to examine an object.

Tuning

The Polilight provides a mechanical means of tilting each filter providing a short range of variation of each filter. It works well but at the expense of reducing the power by about 50% at the maximum tuning (see Table 1). The Spectrum 9000 has a non-tunable filter output (discrete setting) and a continuously variable grating output (variable setting) both using the same lamp. Unfortunately the optics are such that the power output in the variable mode is negligible even at maximum bandwidth of 100 nm (see Table 1, total power). The Luma-Lite can not be tuned.

Quality of Filters

This can be quantitatively judged by the difference in nanometres from the wavelength position of the 50% maximum cut-off point to the 0.1% cut-off point which measures the effectiveness of the filter (see Figure 4 and Tables 1,2 and 3). The further away this point is, the more restricted is the wavelength range available to observe fluorescence (recall that the viewing filter should be to the red side of the excitation cut-off). For the broadband filters used to achieve high power in the blue range such as the 450 nm filter of the Luma-Lite and 530 nm filter of the Spectrum 9000 this difference can be as high as 28 and 24 nm respectively. This is not a problem if sufficient print fluorescence can be observed beyond this point. For most of the remaining narrow band filters it is about 10 nm which shows the attention all manufacturers have paid to this feature.

Uniformity of Beam

The best uniformity is shown by the direct beam of the Luma-Lite. Reasonable uniformity but with a more intense central area is observed for the Polilight through a liquid light guide and the filter wheel system of the Spectrum 9000 through its fibre optic guide. Very irregular spacial distributions of light can be produced (Figure 2) by the liquid guides transmitting the output of the infrared port of the grating (beam a) and filter (beam b) wheel systems of the Spectrum 9000 and the Polilight (beam C). This irregularity is emphasized if the guides are bent sharply. The mottling texture seen in the figures is the structure of the paper sheet that was used to diffuse the beam. It was possible to photograph the infrared beam of the polilight because the film used is sensitive to the far red and near infrared portion of the beam as transmitted by the filter.

Ease of Use

Though this is not a measurable aspect of these light sources, some comments are still warranted, and should be considered by anyone thinking of purchasing one or another of these lamps. At the crime scene or when doing examinations in the laboratory, the three lamps have various drawbacks and advantages.

At the crime scene, the Luma-Lite will provide the brightest light (see Tables), with a uniform cross-section. Usually, crime scenes are searched with the direct output through the filters which necessitates carrying a relatively heavy instrument around the scene. When fingerprints have been located the Luma-Lite can be mounted on a tripod for photographic purposes. The Luma-Lite provides fibre optic capability only in the blue, and at greatly reduced power. The intensity of the beams from the Polilight and Spectrum 9000 can be significantly increased by concentrating their output on to a small area. This, of course, would be counterproductive when searching a large scene. The Polilight and Spectrum 9000, on the other hand, are usually used with either a liquid light guide or fibre optic cable. The machine can be set down in one location, and the wand on the end of the cable used to direct the light around the scene.

The lamps have different filter combinations to cover the wavelength range from the UV to the infrared. In this respect, the Polilight does the best job of covering the entire spectrum with nine tunable filters. The tunability provided by tilting the filters makes it possible to shift the emission maximum, though with loss of power. The Spectrum 9000 has six filters, with gaps in coverage between 520 and 540 rim, and between 590 and 700 nm. The five filters of the Luma-Lite produce good output in the blue region of the spectrum, but poor coverage above 520 nm.

If wavelengths are to be changed, both the Polilight and Spectrum 9000 can do so by simply turning a dial on the front panel of the lamp. The Luma-Lite requires physically removing each filter that has to be replaced.

CONCLUSION

The choice of lamp will generally depend on the intended use. For crime scene searches power will be a major consideration and from these measurements the Luma-Lite provides greatest power in the wavelengths most useful for this purpose. For laboratory examinations, and use in other disciplines such as examination of questioned documents, the Polilight may offer the best combination of filters and tunability.

Both the Polilight and the Spectrum 9000 produce UV and IR emission, although the latter has significantly increased power output in these regions compared to the former. The Luma-Lite does not produce significant output in either of these regions of the spectrum.

This study does not represent an endorsement of any particular lamp by the RCMP. We simply present our results so that the police community may have additional information to that in the promotional literature of the manufacturers.

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Table I Spectral Output of the Polilight

Filter (nm)	Cut-on, 0.1% (nm)	50% Cut-on 3 - 50% Cut-off 4 (nm) 5	Peak (nm) 6	Cut-off 0.1% 2 (nm) 7	Total power 8 (Watts) 9		
White							5.38
350	308	340 – 372	348	398	0.16– 0.07	(32)	(26)
415	388	396 – 434	410	452	0.30- 0.05	(38)	(18)
450	418	426 – 482	468	492	0.56- 0.20	(56)	(10)
505	480	486 – 524	494	530	0.44- 0.30	(38)	(6)
530	506	512 – 550	530	560	0.44- 0.28	(38)	(10)
555	536	546 – 568	554	578	0.28- 0.12	(22)	(10)
590	558	566 – 604	570	616	0.44- 0.24	(38)	(12)
620	594	602 – 640	608	652	0.28- 0.22	(38)	(12)
650	626	634 – 656	640	676	0.16- 0.12	(22)	(20)
>700					0.35		

KEY (see Figure 4)

- 1, 2 The wavelengths at which the output is 0.1% of the peak output
- 3, 4 The wavelengths at which the output is 50% of the peak output
- 5 The difference in nanometres between the 50% cut-on and cut- off points (sometimes referred to as the Full Width Half Maximum, FWHM)
- 6 The wavelength of maximum output. Due to variation in the source output this often is not in the centre of the bandwidth
- 7 The distance in nanometres between the 50% and 0.1% cut-off points. This value gives a measure of the sharpness of filter cut-off
- 8 Total power in watts passing through a 5 cm diameter intersect of the beam
- 9 First value is from the untuned filter and the second value is using maximum tuning

Table 2 Spectral Output of the Spectrum 9000

Filter (nm)	Cut-on 0.1% 1 (nm)	50% cut-on 3 -cut-off 4 (nm) 5	Peak 6 (nm)	Cut-off 0.1% 2 (nm) 7	Total Power (Watts) 8,9 L -F	Total Power (Watts) 8,10 L -F
400	380	390 - 410 (20)	402	434 (24)	1.24 - 0.57	0.00 - 0.01
450	418	430 – 462 (32)	450	472 (10)	0.35 - 0.80	0.01 - 0.04
485	452	464 – 502 (38)	474	514 (12)	0.59 - 1.32	0.01 - 0.04
530	398	448 – 508 (60)	474	832 (24)	1.18 - 2.88	0.01 - 0.04
570	536	556 – 578 (22)	566	596 (18)	0.45 - 0.80	0.01 - 0.03
700	676				7.70 - 0.09	0.01 - 0.01

KEY

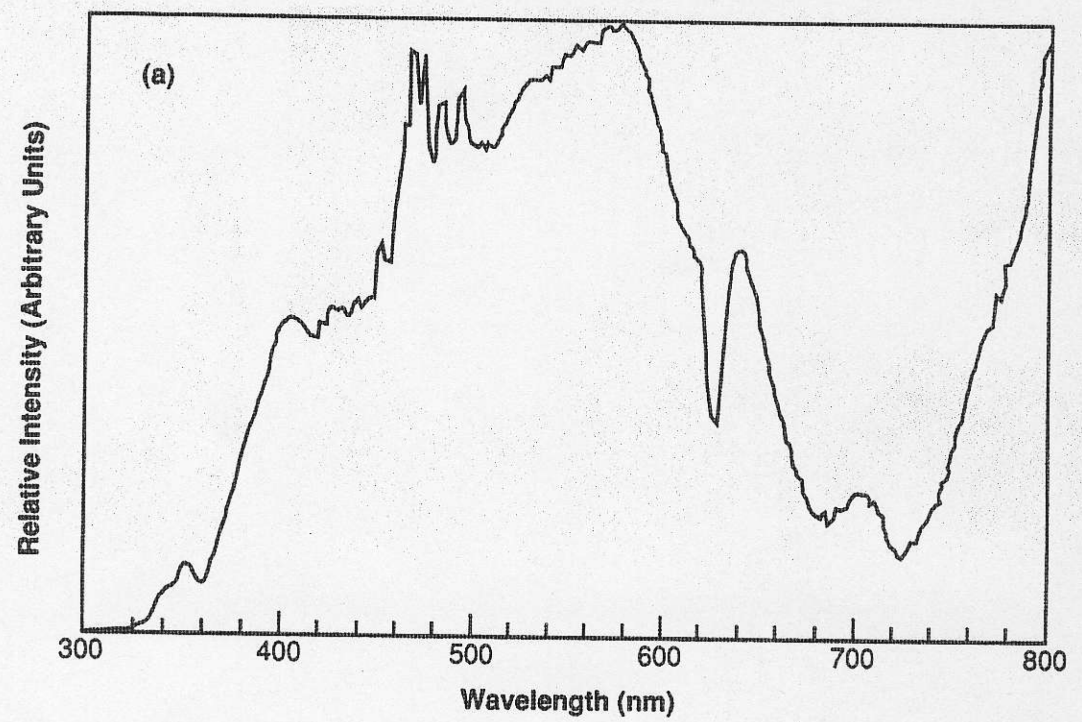
- 1-8 As for Table 1
- 9 Discrete (filter wheel) output port
- 10 Variable output port (grating monochromator with bandwidth set at 100 nm)
- L liquid light guide
- F fibre optic guide

Table 3 Spectral Output of the Luma-Lite

Filter (nm)	Cut-on 0.1% 1 (nm)	50% Cut-on 3 50% Cut-off 4 (nm) 5	Peak 6 (nm)	Cut-off 0.1% 2 (nm) 7	TotalPower 8 (Watts)
White					34.80
UV					0.08
450	360	424 – 496 (72)	468	524 (28)	11.90 0.90 9
485	462	488 – 508 (20)	502	530 (22)	0.96
530	514	528 – 538 (10)	532	548 (10)	0.78
570	558	570 – 580 (10)	574	592 (12)	0.78

KEY

- 1 - 8 As for Table 1
- 9 Total power through the fibre optic guide



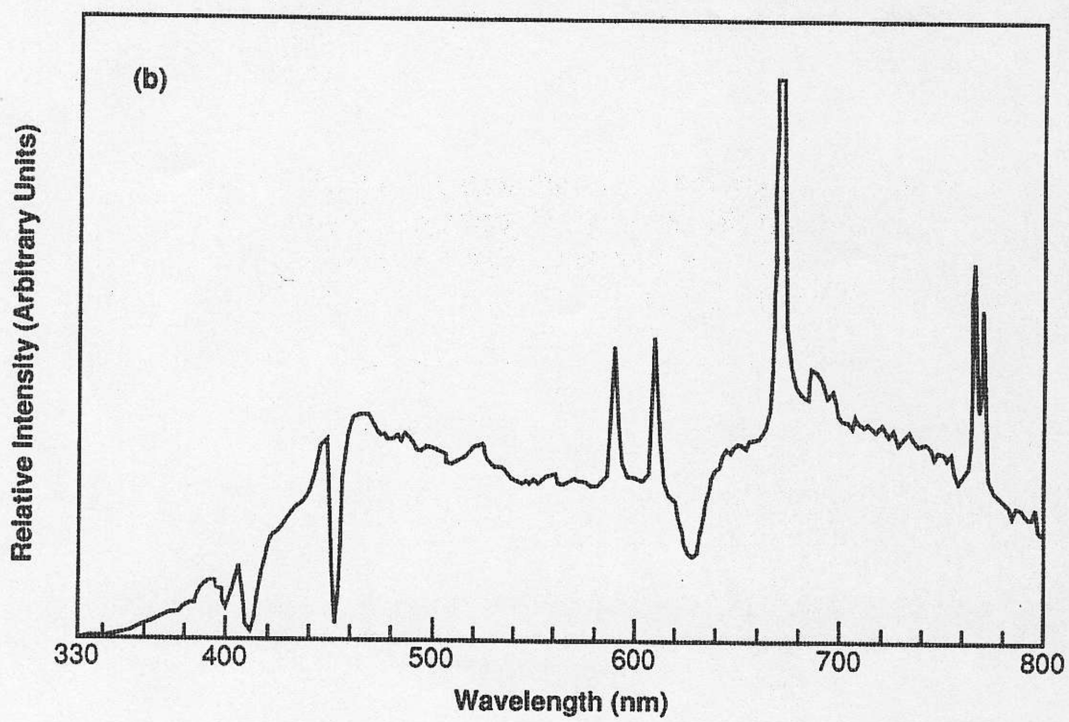


Figure 1 Corrected Spectral Output
(a) Xenon Arc Lamp of the Polilight through the infrared filter
(b) Indium MARC Lamp of the Luma-lite

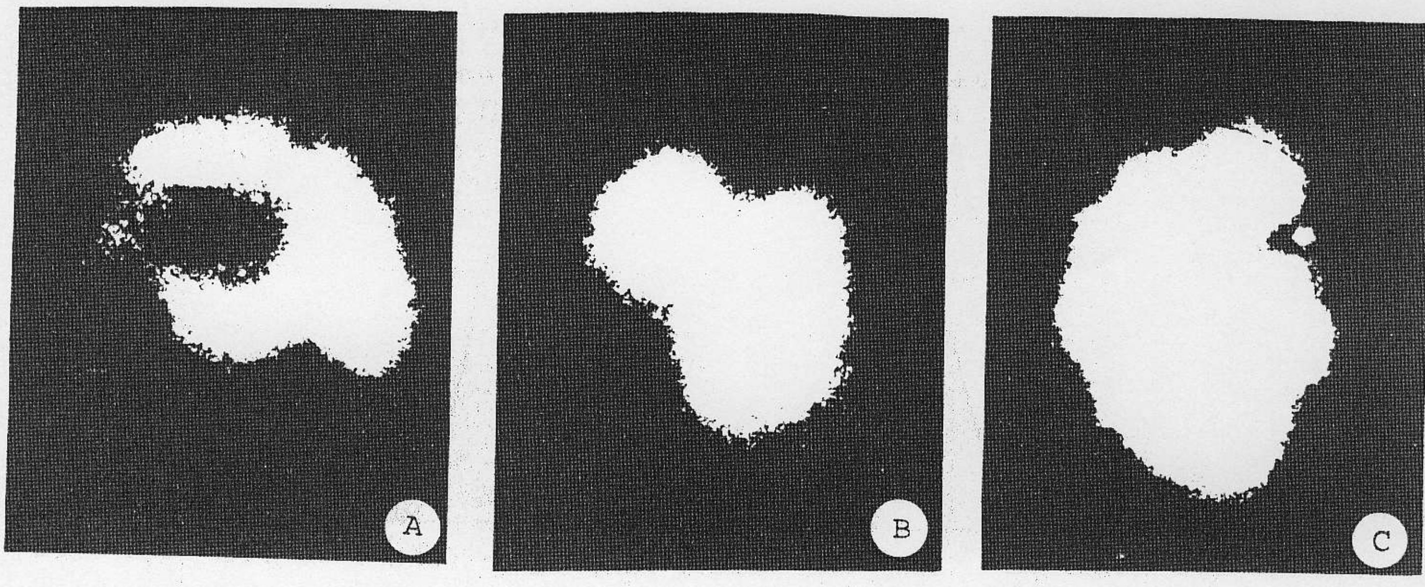


Figure 2 Uniformity of Beam in a 5 cm Diameter Circle
(A) Spectrum 9000, grating system, liquid guide
(B) Spectrum 9000, filter system, liquid guide
(C) Polilight, infrared fibre optic guide

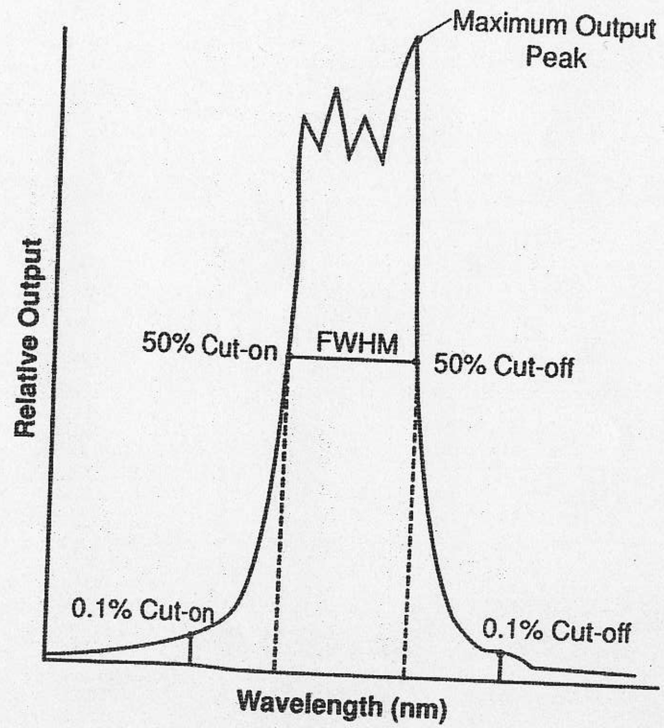


Figure 3 Generic Lamp Output Spectrum

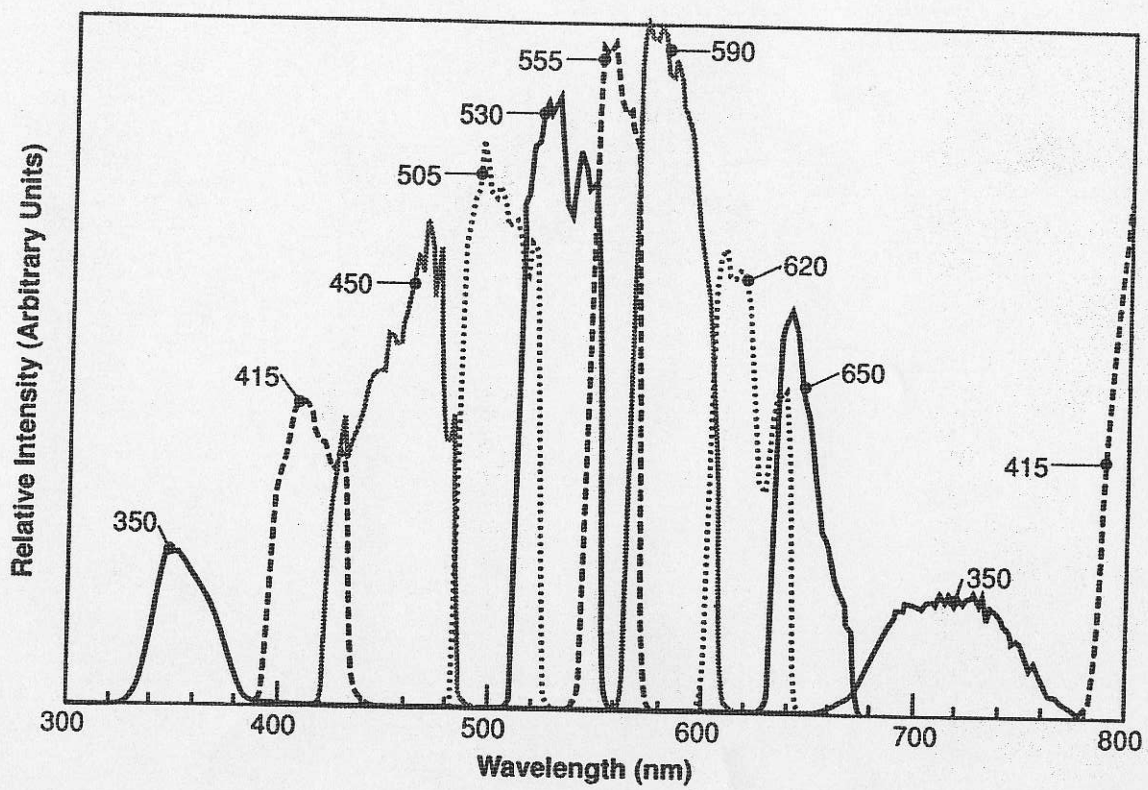


Figure 4 Corrected Spectral Output for Filters of the Polilight

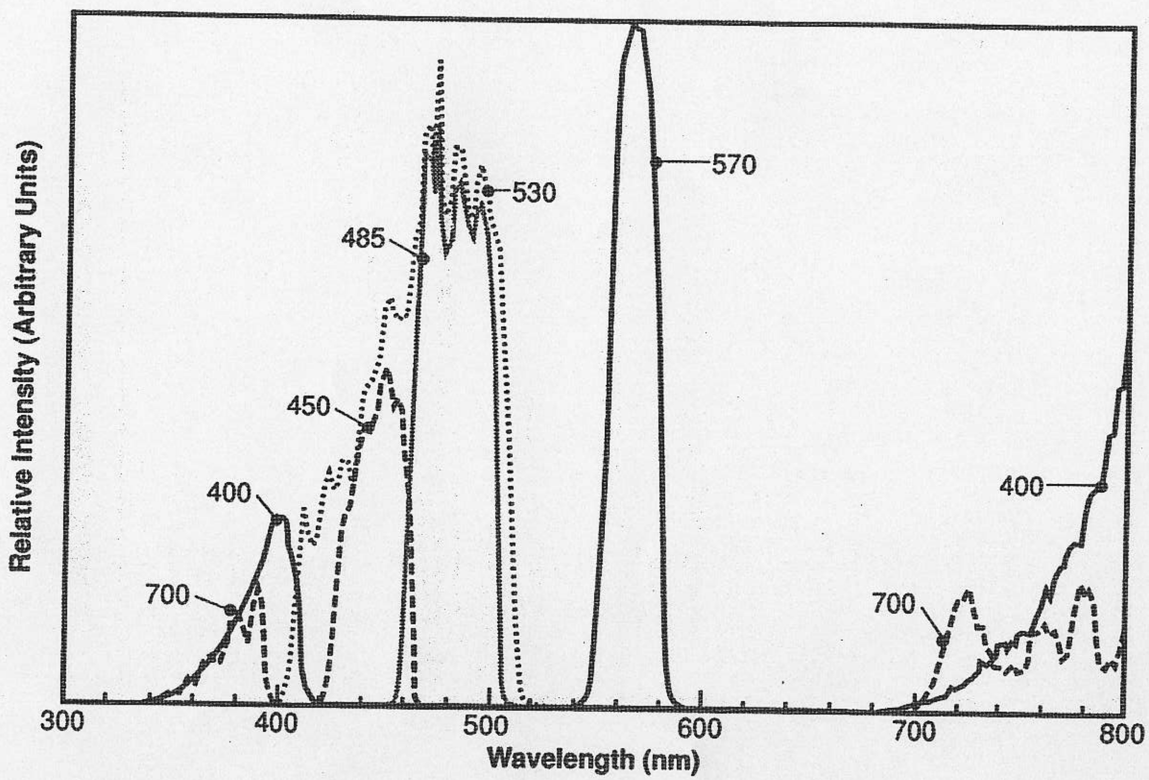


Figure 5 Corrected Spectral Output for Filters of the Spectrum 9000

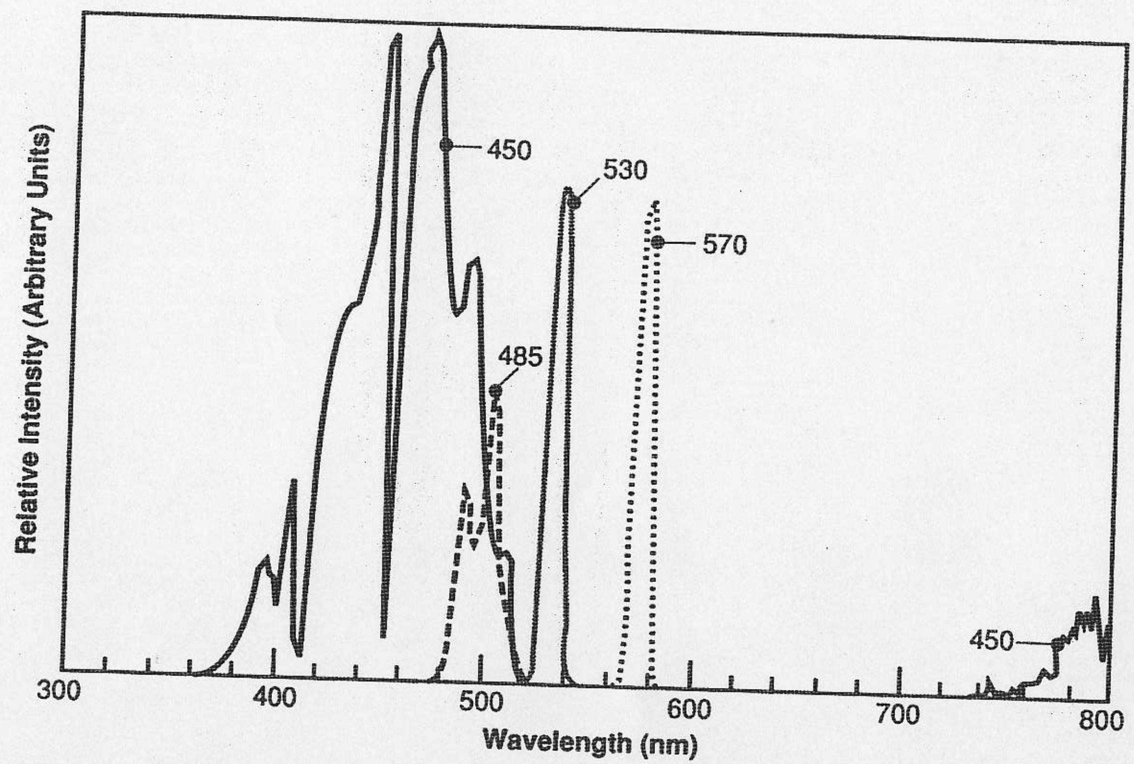


Figure 6 Corrected Spectral Output for Filters of the Luma-Lite