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A Study of the Near Ultraviolet Emission of Tellurium-Doped Xenon Flashlamps

Richard E. Palmer, Merrill A. Palmer

Sandia Laboratories

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A STUDY OF THE NEAR ULTRAVIOLET EMISSION
OF TELLURIUM-DOPED XENON FLASHLAMPS

Richard E. Palmer
Laser Physics Research Division
and
Merrill A. Palmer
Laser & Plasma Physics Research Division
Sandia Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

High-current Xe-filled flashlamps were doped with Te in an attempt to enhance the near ultraviolet emission in the spectral region 250-290 nm. The addition of Te resulted in flashlamp performance similar to that of an undoped flashlamp in the high pressure limit.

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I. Introduction

The atomic iodine photodissociation laser has several characteristics which make it a potentially attractive candidate as the laser driver in inertial confinement fusion.¹ However, one major drawback of this laser is its marginal efficiency with conventional pump sources, which are typically Xe-filled short pulse width quartz flashlamps. In the spectral region of the atomic iodine laser (250-290 nm), high-current Xe-filled short pulse width quartz flashlamps have a spectral efficiency of $\sim 0.1\%/nm$.²⁻⁶ Previous studies have indicated that the near ultraviolet spectral efficiency of Xe flashlamps can be enhanced by the addition of metal additives.⁷⁻⁹ All of these studies have been with flashlamps for which the pulse duration was $\geq 10 \mu sec$. For reasons of optimal regeneration of the initial parent compound¹⁰ and of avoidance of optical distortion of the gain medium¹¹⁻¹³ the pulse duration of flashlamps driving an atomic iodine laser should be $\sim 1 \mu sec$. The purpose of the present study was to determine if the addition of a metal additive would enhance the ultraviolet spectral efficiency of Xe-filled flashlamps with a pulse duration $< 10 \mu sec$. Tellurium was selected as the dopant, not only because it has a relatively low vaporization energy, but also because it was observed that it added less of a tail to the near ultraviolet emission of Xe-filled flashlamps than other dopants.¹⁴ The latter consideration is especially important if the pulse duration of the near ultraviolet emission is to be $< 10 \mu sec$.

Section II describes the experimental apparatus, including the flashlamp assembly, pulse-forming network, and means of recording the emission spectra and intensity of the flashlamps. Section III discusses the experimental results, and Section IV summarizes the conclusions of the study.

II. Experimental Apparatus

The flashlamp assembly and pulse-forming network are shown in Fig. 1. Two stainless steel 1/2" Swagelok¹⁵ crosses are supported on 1/2" diameter oxygen-free copper posts. The oxygen-free copper electrodes are screwed directly to the posts; access to the screws is through the top Swagelok ports, which are plugged after assembly of the electrodes. The end port on the left Swagelok cross is also plugged. (A Swagelok tee does not have enough inside clearance for the electrodes and posts.) Nylon ferrules are used for quick disassembly of the ports, but stainless steel or teflon ferrules would suffice. The clear fused quartz envelope¹⁶ has a wall thickness of 1 mm. The outer diameter is 12 mm in the region surrounding the electrodes. The envelope is necked down to a smaller diameter in the discharge region in order to adjust the K_0 - value¹⁷ of the flashlamp to critically damp the circuit. The length of the discharge region between the electrodes is 10 cm. The quartz envelopes are sealed to the Swagelok ports with teflon ferrules, because nylon ferrules are stiffer and tend to crack the quartz envelope upon tightening. The end port on the right Swagelok cross is connected to a vacuum system (base pressure 5×10^{-7} Torr) and to a gas manifold with which the flashlamps can be filled with the desired gas, usually Xe.

Two pulse-forming networks were used in the study. The first consisted of a Maxwell 31161 0.70 μ F capacitor and a Tachisto 301 spark gap. The inductance was minimized by running the oxygen-free copper return plate as close to the flashlamp as possible. The inductance of the pulse-forming network was determined to be 0.16 μ H by measuring the circuit ringing frequency with an aluminum-bar dummy load in place of the flashlamp, which is a non-linear load.¹⁷ The flashlamp inner diameter (bore) was chosen to be 4 mm in order to critically damp the circuit. The pulse width (FWHM) of the current

Figure 1. Diagram of flashlamp assembly and pulse-forming network.

pulse (as measured by a Pearson 1025 current monitor transformer terminated in 50 Ω) was ~ 1 μ sec. A Mylar insulating sheet was placed between the flashlamp and the copper return plate. A diffuse black sheet was placed in front of the Mylar to remove spurious reflections of the flashlamp light.

The second pulse-forming network consisted of a Sangamo 14.2 μ F capacitor and a Tachisto 101 spark gap. In this case, the flashlamp bore was 8 mm. The circuit inductance was determined to be 0.18 μ H and the current pulse width (FWHM) was ~ 5 μ sec.

In all cases the flashlamp was simmered with 15 mA dc provided by a high voltage power supply and a 100 k Ω external resistor (not shown in Fig. 1). For the conditions investigated, the flashlamps were significantly less efficient and less reliable without the simmer present. This is probably due to an increase in the arc channel growth time of these short pulse width flashlamps.

A Spex 1500 SP 3/4 m Czerny-Turner spectrometer and an ITT vacuum photodiode were used to record the flashlamp output spectrum and intensity. The spectrometer grating had 1200 g/mm and was blazed at 300 nm. The spectrometer was used in first order, and the reciprocal linear dispersion was 1.1 nm/mm. The spectrometer was in the plane normal to the flashlamp axis, and the flashlamp was imaged on the spectrometer entrance slit with a 0.236-cm diameter aperture. The distance from the aperture to the entrance slit was 68 cm, and the distance from the aperture to the flashlamp was 62 cm. The flashlamp emission from 240 nm to 300 nm was recorded on Polaroid type 57 film.

The spectrometer system was calibrated in the following manner. An Optronic Laboratories model UV-40 deuterium arc lamp (designation UV-204), which is absolutely calibrated (traceable to NBS), was placed 125 cm from the spectrometer entrance slit. The 0.236-cm aperture was temporarily removed.

The entrance slit width was set to 250 μm . Several exposures were taken with an electronically timed shutter ranging from 0.2 sec to 5 sec. This range spanned the entire film exposure range from below threshold to above saturation. Reciprocity corrections are a potential problem, since the system was calibrated at times ~ 1 sec and the experimental time scale was ~ 1 μsec . Comparison of the spectrometer data to photodiode data (see Section III) was used as a check on the effects of reciprocity. Good agreement between the spectrometer data and the photodiode data indicates that while reciprocity may produce a systematic error in the spectrometer calibration, it does not contribute significantly to the overall error of the measurements.

The film exposures were scanned and digitized by a densitometer. A curve of film exposure (i.e. reflectivity) vs. spectral irradiance ($\text{J}/\text{cm}^2\text{-nm}$) at the spectrometer entrance slit was generated at wavelength intervals of 10 nm. The film was calibrated in wavelength independently with a low pressure mercury lamp. From these curves a family of curves of reflectance vs. wavelength with the spectral irradiance as a parameter was produced. This family of curves is shown in Fig. 2. Note that the spectrometer efficiency increases at longer wavelengths, because of the increased reflectivity of the optical components such as the grating and mirrors at longer wavelengths. Figure 2 was used to find the spectral irradiance corresponding to a given wavelength and film reflectivity. The spectral irradiance was determined in general by linearly interpolating between the iso-irradiance contours. In the case of the 8-mm bore flashlamps, the entrance slit width was reduced to 100 μm , so that the spectral irradiance had to be multiplied by 2.5 to obtain an absolute value. The overall uncertainty in the determination of spectral irradiance in the above manner is $\pm 15\text{-}20\%$.

The vacuum photodiode was an ITT model F4000 (S5) terminated in 50 Ω .

Figure 2. Reflectance of Polaroid Type 57 film as a function of spectral irradiance ϵ at the entrance slit and of wavelength.

An interference filter with a peak transmission of 15% at 280 nm and a bandwidth (FWHM) of 20 nm was placed before the photodiode. The photodiode was 19.6° from the plane normal to the flashlamp axis and was a distance of 145 cm from the flashlamp. The photodiode and interference filter were absolutely calibrated together by placing the Optronic Laboratories D₂ arc lamp at a distance of 30 cm from the interference filter plane. The light was chopped at 100 Hz with a mechanical chopping wheel. The D₂ arc lamp spectrum was not convoluted into the interference filter transmission function, since the emission spectrum varies smoothly and slowly over the bandwidth of the filter (+19% and -16% at the short and long wavelength half-power points of the filter, respectively, compared to the central value). Rather, the lamp spectral irradiance was approximated by the central value at 280 nm. The detector response was determined to be 15.1 V/(W/cm²-nm) at 280 nm when the photodiode is terminated in 50 Ω .

III. Experimental Results

Attempts to dope the flashlamps by vaporizing the initial powdered Te charge with the main discharge always produced unreliable results, primarily because the ensuing Te film was not uniform or even opaque. In an earlier study¹⁸ on metal-doped flashlamps, ILC Technology, Inc., observed similar results. Gusinow¹⁹ has since indicated that reliable plating of the metal dopant was difficult to achieve until after phosphorus, which has a high vapor pressure, was introduced into his system for study as a dopant material. Presumably the ILC vacuum system was free of high vapor pressure materials, and care was taken in the present experiment to avoid the introduction of high vapor pressure materials into the vacuum system. (The system was not baked out because of the presence of nylon and teflon ferrules.) This suggests

that perhaps phosphorus is important to reliable doping of metal additives.

Consequently, another technique was developed to produce good Te films. Initially, 50 mg (100 mg) Te powder was distributed uniformly along the length of the 4-mm (8-mm) bore flashlamp. A few Torr of Xe was introduced into the flashlamp in order to maintain a discharge, and the simmer current was run at 5-10 mA. This heated the flashlamp, and the Te powder would slowly evaporate and condense on the flashlamp inner wall. The simmer current was critical, because if the temperature was too low, the Te would not evaporate, and if the temperature was too high, the Te would not condense on the flashlamp inner wall and would instead diffuse behind the electrodes, where it was cooler. The process was essentially trial and error, but good Te films (as characterized by being shiny and opaque) could frequently be produced in this manner. Once a good film was produced, the results were reproducible and consistent. The results presented below are for doped flashlamps prepared in the above way.

In addition, the flashlamps were masked with diffuse black paper so that only the central 2 cm was exposed. Tests performed on undoped flashlamps indicated that the emission was uniform over the 10-cm arc length. The masking was done because it was difficult to produce a good Te film over the entire 10-cm arc length.

Figures 3, 4 and 5 show the current and photodiode signal for 4-mm bore flashlamps at several Xe pressures at charge voltages of 10 kV, 13.5 kV and 17 kV, respectively. In addition, there is a photograph of the current and photodiode signal for a Te-doped 4-mm bore flashlamp at a charge voltage of 13.5 kV. The first pulse-forming network (0.70 μ F) was used for Figs. 3-5. Figure 6 shows similar data for undoped 8-mm bore flashlamps at several

10 Torr Xe

20 Torr Xe

40 Torr Xe

2 μ sec

60 Torr Xe

80 Torr Xe

Figure 3. Current trace (upper curve) and photodiode trace (lower curve) for 4-mm bore flashlamp at a charge voltage of 10 kV and a capacitance of 0.7 μ F.

10 Torr Xe

20 Torr Xe

40 Torr Xe

60 Torr Xe

80 Torr Xe

60 Torr Xe + Te

Figure 4. Current trace (upper curve) and photodiode trace (lower curve) for 4-mm bore flashlamp at a charge voltage of 13.5 kV and a capacitance of 0.7 μ F.

Figure 5. Current trace (upper curve) and photodiode trace (lower curve) for 4-mm bore flashlamp at a charge voltage of 17 kV and a capacitance of 0.7 μ F.

Figure 1. Current trace (upper curve) and photonic trace (lower curve) for semi-conductor diodes at a charge voltage of 5 kV and a capacitance of 100 pF.

Te-doped lamps and the undoped lamp were flashtube using the second pulse-forming network (Fig. 2B). Data for doped flashtubes were virtually independent of Xe pressure at pressures ≤ 10 Torr, presumably due to the fact that, at low Xe pressure, dense plasma ensues from vaporization of the Te which prevents the Xe radiation from the flashtube interior and was probably the main source of emission.

The peak current for the first pulse-forming network was 8 kA, 11 kA, and 14 kA for charge voltages of 10 kV, 13.5 kV, and 17 kV, respectively. The effect of charge voltage on flames was greatest at 13.5 kV. At 10 kV there was little effect and even the Te was not effectively vaporized (nor was the silicon in the undoped flashtube at this voltage). At 17 kV the overall flashtube performance was not as efficient as at 13.5 kV.

The peak current in Fig. 6 is 20 kA at a charge voltage of 5 kV for the second pulse-forming network. This is similar to the peak current for much of the work reported in Ref. 8 on 4-mm bore doped flashtubes.^{8,9,14}

It can be seen from Figs. 3-6 that neither the Xe pressure nor the amount of Te dopant affected the current appreciably. The photodiode signal did vary, however, as these two parameters, however. Observe in addition that the photodiode signal in the case of the Te-doped lamps does not have a large peak value. Initially, when the film was still thick, the photodiode signal actually had a lower peak value, but had a larger integrated area due to a longer pulse width. As more shots were taken, the Te film became thinner, and the photodiode signal gradually approached that of an undoped flashtube with 60 Torr Xe. That is to say, the peak signal slowly increased and the pulse width slowly decreased as more shots were taken.

The photodiode signals in Figs. 3-6 were numerically time-integrated to determine the spectral irradiance over the bandwidth of the interference

filter. Recall that the photodiode and interference filter were 145 cm from the flashlamp and 19.6° from the plane normal to the flashlamp axis. The results were divided by the appropriate capacitor stored energy to determine the spectral irradiance efficiency. This latter parameter is plotted in Fig. 7. The uncertainty in the data is $\sim \pm 15\%$ and is due primarily to the uncertainty in the Optronics Laboratories D₂ arc lamp absolute calibration and to the numerical integration of the photodiode signals. Because the output spectrum is a function of pressure (see below) and of charge voltage, the data shown in Fig. 7 should be compared with some caution; however, the interference filter performs a weighted average over a 20-nm bandwidth, and this effect does not qualitatively affect the photodiode data (as determined by comparison to spectrometer data presented below). The upper and lower dashed lines correspond to the value for Te-doped flashlamps using the 14.2 μF and 0.70 μF capacitors, respectively. It can be seen that the spectral irradiance efficiency increases as the Xe pressure increases. The value for the Te-doped flashlamps is close to the high pressure asymptote for the undoped lamps. This, too, is consistent with the concept of the Te acting to provide a hot plasma with a density close to solid density that is the primary source of the flashlamp emission. In the case of the 4-mm bore flashlamps using the 0.7 μF capacitor, the spectral irradiance efficiency at 10 kV rises more rapidly with Xe pressure than at 13.5 kV or at 17 kV. This is due to the fact that at 10 kV most of the radiation was Xe line emission and was, therefore, very dependent on the Xe pressure. At 13.5 kV and at 17 kV (and for the 8-mm bore flashlamps), a good part of the emission at 280 ± 10 nm was due to Si I emission produced by ablation of the tube inner wall. This is evident from the spectra taken with the spectrometer. Hence, under these conditions, the emission at 280 ± 10 nm

Figure 7. Spectral irradiance efficiency of Xe flashlamps at 280 ± 10 nm at a distance of 145 cm (19.6° from normal plane): ○ - 4-mm bore, 0.70 μ F, 10 kV; X - 4-mm bore, 0.70 μ F, 13.5 kV; Δ - 4-mm bore, 0.70 μ F, 17 kV; □ - 8-mm bore, 14.2 μ F, 5 kV. The lower (upper) dashed line is the value for a Te-doped 4-mm (8-mm) bore flashlamp at all Xe pressures. All but the central 2 cm of the 10-cm arc length has been masked.

was not as rapidly increasing a function of Xe pressure.

Typical spectra taken with spectrometer are presented in Figs. 8-13. Figure 8 is the spectrum from a 4-mm bore flashlamp with 20 Torr Xe and at a charge voltage of 13.5 kV. Several Xe and Si lines are superimposed on a moderate continuum background. Note, in particular, the self-reversed Si I lines at 251 nm and at 288 nm. The general rise in reflectance at longer wavelengths is due principally to the higher efficiency of the spectrometer (see Fig. 2 and associated discussion). Figure 9 is the spectrum from a 4-mm bore flashlamp with 60 Torr Xe and at a charge voltage of 13.5 kV. The spectrum is quite similar to that in Fig. 8, except that the background continuum is somewhat greater. Figure 10 is the spectrum from a 4-mm bore Te-doped flashlamp with 60 Torr Xe and at a charge voltage of 13.5 kV. The spectrum is now almost entirely a continuum, without much evidence of line emission. The spike at 242 nm is a re-entrant spectrum produced in the spectrometer itself and is not in the flashlamp emission spectrum. Since it is in all the spectra, it does serve as a convenient wavelength fiducial.

Figures 11 and 12 are spectra of 8-mm bore flashlamps at a charge voltage of 5 kV with 20 Torr Xe and 60 Torr Xe, respectively. As for the 4-mm bore undoped flashlamps, strong Xe and Si line spectra are evident. Figure 13 is the spectrum from an 8-mm bore Te-doped flashlamp with 60 Torr Xe and at a charge voltage of 5 kV. The spectrum is primarily a continuum. There is a very narrow absorption line attributed to Te I ($5p^4 \ ^3P_1 - 6s \ ^5S_2$) at 253 nm, however. The width of this line is unresolved, and it is not clear whether or not the presence of this absorption line is consistent with the picture of a hot, dense Te plasma. Nevertheless, the emission spectrum of Te-doped flashlamps is basically that of a continuum and is characteristic

Figure 8. Reflectance vs. wavelength for 4-mm bore, 20 Torr Xe flashlamp. The charge voltage is 13.5 kV and the capacitance is 0.70 μ F. The entrance slit width is 250 μ m.

Figure 9. Reflectance vs. wavelength for 4-mm bore, 60 Torr Xe flashlamp. The charge voltage is 13.5 kV and the capacitance is 0.70 μ F. The entrance slit width is 250 μ m.

Figure 10. Reflectance vs. wavelength for 4-mm bore, 60 Torr Xe + Te flashlamp. The charge voltage is 13.5 kV and the capacitance is 0.70 μ F. The entrance slit width is 250 μ m.

Figure 11. Reflectance vs. wavelength for 8-mm bore, 20 Torr Xe flashlamp. The charge voltage is 5 kV and the capacitance is 14.2 μ F. The entrance slit width is 100 μ m.

Figure 12. Reflectance vs. wavelength for 8-mm bore, 60 Torr Xe flashlamp. The charge voltage is 5 kV and the capacitance is 14.2 μ F. The entrance slit width is 100 μ m.

Figure 13. Reflectance vs. wavelength for 8-mm bore, 60 Torr Xe + Te flashlamp. The charge voltage is 5 kV and the capacitance is 14.2 μ F. The entrance slit width is 100 μ m.

of the emission to be expected from an undoped flashlamp at extremely high plasma densities.

Other noble gases such as Ar were tried in doped flashlamps in place of Xe. In all cases the doped flashlamps with Xe as the principal gas were much more efficient. There was some indication that the Te was inefficiently vaporized with the other noble gases, but the evidence with regard to this observation was not conclusive.

Flashlamp Efficiency - The photodiode data and the spectrometer data for the six shots described in Figs. 8-13 were used to estimate the overall flashlamp efficiency in these cases. Table I lists the lamp size, fill, and energy for the six cases. The spectral irradiance at a wavelength of 280 nm and at a distance of 145 cm is given in the fourth column in Table I. The values are for the plane normal to the flashlamp axis, so the photodiode data has been multiplied by $\sec 19.6^\circ$. The first entry in column 4 is the photodiode result; the second is the spectrometer result. Given that the uncertainty in the photodiode data is $\pm 15\%$, and the uncertainty in the spectrometer data is at least $\pm 15-20\%$, the agreement is surprisingly good.

In order to calculate the overall spectral irradiance from the photodiode data, the observed spectral irradiance was multiplied by a factor of 5. This is to account for the fact that only 2 cm of the 10-cm arc length was exposed to the photodiode.

The determination of the spectral irradiance from the spectrometer data required a slightly more complicated correction for the observed area. The 0.236-cm diameter aperture allowed a viewing area equal to a circle with a radius of 0.226 cm at the flashlamp. In the case of the 8-mm bore flashlamps the spectral irradiance from the entire flashlamp was calculated by

TABLE I

Flashlamp Spectral Irradiances and Efficiencies

Lamp Size ^a (cm)	Lamp Fill	Energy (J)	Spectral Irradiance ^b $\mu\text{J}/\text{cm}^2 \cdot \text{nm}$	Efficiency ^c
10 x 0.4	20 Torr Xe	63.8	0.19, 0.19	0.024, 0.027
10 x 0.4	60 Torr Xe	63.8	0.29, 0.28	0.038, 0.034
10 x 0.4	60 Torr Xe +Te	63.8	0.35, 0.33	0.046, 0.044
10 x 0.8	20 Torr Xe	177.5	0.94, 1.0	0.044, 0.045
10 x 0.8	60 Torr Xe	177.5	1.2, 1.3	0.054, 0.058
10 x 0.8	60 Torr Xe +Te	177.5	1.7, 1.6	0.077, 0.076

a. Arc length x bore.

b. Calculated for a wavelength of 280 nm and for a distance of 145 cm normal to lamp axis; first number is from photodiode, second is from spectrograph.

c. A flat 40-nm bandwidth in the photodiode case and a Lambertian spatial distribution are assumed; first number is from photodiode, second is from spectrograph.

multiplying the observed spectral irradiance by $(10 \text{ cm} \times 0.8 \text{ cm})/\pi(0.226 \text{ cm})^2$. This assumes that the flashlamp is a Lambertian source (see below), so that the irradiance is proportional to the projection of the radiating surface at the point of detection. In the case of the 4-mm bore flashlamps, refractive effects in the 1-mm quartz wall ($n \approx 1.5$ at 280 nm^{20}) cause the emission to be vignettted if it originates from the flashlamp inner wall at a vertical distance greater than 0.185 cm above or below the flashlamp axis. The effective area seen by the spectrograph entrance slit was therefore approximated by an ellipse with a horizontal (major) radius of 0.226 cm and a vertical (minor) radius of 0.185 cm. Hence the spectral irradiance from the entire 4-mm bore flashlamp was calculated by multiplying the observed irradiance by $(10 \text{ cm} \times 0.4 \text{ cm})/\pi(0.226 \text{ cm} \times 0.185 \text{ cm})$. The entries in column 4 of Table I have been corrected in the above ways to represent the spectral irradiance from the entire flashlamp radiating area. The spectral irradiance determined from the spectrometer data has also been multiplied by $(130 \text{ cm}/145 \text{ cm})^2$ in order to calculate the spectral irradiance at 145 cm, so that it can be compared directly to the result from the photodiode data.

In order to determine the flashlamp efficiency, two more approximations were necessary. The spatial distribution and usable spectral bandwidth had to be included.

Reference 5 assumes that the radiation is emitted isotropically. This is not to be expected for a non-spherical surface radiator. Instead, a Lambertian distribution for which the intensity is proportional to the projection of the radiating surface at the point of detection, is more likely. In the case of the flashlamps investigated in this experiment, this would mean that the radiation intensity is proportional to $\sin \theta$, where θ is the polar angle with respect to the flashlamp axis.

The photodiode was moved in the horizontal plane between 0° and 45° from the plane normal to the flashlamp axis ($\theta = 90^\circ - 135^\circ$). The distance to the flashlamp was kept at 145 cm. The angular distribution of the radiation emitted from undoped flashlamps was consistent with a distribution proportional to $\sin \theta$ over the angular range investigated. The angular distribution of the emitted radiation was not fit well by an isotropic distribution. Hence, a factor of $\langle \sin \theta \rangle = \frac{\pi}{4} \approx 0.785$ must be included in any calculation of the overall flashlamp efficiency from the irradiance in the plane normal to the flashlamp axis.

The usable bandwidth of the absorption band of an atomic iodine laser using $\text{C}_3\text{F}_7\text{I}$ as the parent compound is often assumed to be 250-290 nm.^{5,21} For consistency, the same 40-nm bandwidth is assumed here. The spectra in Figs. 8-13 were numerically integrated by first digitizing the data between 250 nm and 290 nm into 502 points. The data were then point-by-point interpolated by comparison to the iso-irradiance contours, which were also digitized by a linear interpolation between the measured calibration points at 10 nm intervals. The normalized spectral irradiance was finally integrated to give the total irradiance over the 40-nm bandwidth.

When the spectral response of the spectrometer is convolved into the spectra of Figs. 8-13, the average spectral irradiance is reasonably flat between 250-290 nm. Thus, for the purpose of calculating the flashlamp efficiency from the photodiode data, the spectral irradiance measured by the photodiode was simply multiplied by the 40-nm bandwidth to obtain the total irradiance. While it is true that the photodiode spectral irradiance is already a weighted average (performed by the interference filter) over half the 40-nm bandwidth, the efficiency inferred from

the photodiode data can be considered only as approximate, since the complicated line structure, especially for the undoped flashlamps, is not accounted for accurately.

Given the above assumptions, the overall flashlamp efficiency was calculated from the total irradiance by multiplying it by $4\pi(145 \text{ cm})^2 < \sin^2 \theta > / E$, where $E = \frac{1}{2} CV^2$. The results for the photodiode data and spectrograph data are listed in column 5 of Table I. In the present study, the efficiency of Xe-filled short pulse width quartz flashlamps is $\sim 0.1\%/nm$, in agreement with previous studies.²⁻⁶ The efficiency of Te-doped flashlamps is slightly higher ($\sim 30\%$) than undoped flashlamps with 60 Torr or more Xe, but the overall efficiency decreases at shorter pulse widths, probably because there is insufficient time for arc channel growth during the flash.

IV. Conclusions

The addition of a metal additive such as tellurium to a Xe-filled quartz flashlamp makes the near ultraviolet emission very similar to that to be expected from a very high pressure undoped flashlamp. While doping does enhance the near ultraviolet emission slightly, the degree of enhancement is such that an atomic iodine laser pumped by metal-doped Xe-filled flashlamps would not have an acceptable electrical efficiency as the driver in inertial confinement fusion. This is especially true if $1 \mu\text{sec}$ pulse width flashlamps are necessary for efficient parent compound recovery and for good gain medium optical homogeneity.

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