ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA

VOL. LIV, 7 SECTIO AAA 1999

Instytut Fizyki UMCS,
20-031 Lublin, Pl. M. Curie-Skłodowskiej 1, Poland

LESZEK MICHALAK, HALINA FELIŃSKA*
and ARTUR MARKOWSKI

Distribution of ions generated along the focused photon beam intersected by the effusion molecular beam

Rozkład jonów wytwarzanych wzdłuż zogniskowanej wiązki fotonów przecinanej efuzyjną wiązką molekularną

ABSTRACT

In this work results of calculations of the number of photo-ions generated along a focused photon beam intersected with an effusion molecular beam as a function of the geometrical parameters of the effusion capillary, the parameters of the photon beam and the mutual position of both beams are presented. In the described case the axes of both beams are parallel to each other.

1. INTRODUCTION

A simple, but very effective inlet system of neutrals for time-of-flight mass spectrometers is an effusion molecular beam emitted from a capillary

* Katedra Matematyki i Geometrii Inżynieryjnej, Politechnika Lubelska, 20-618 Lublin, ul. Nadbystrzycka 40, Poland.

positioned between the electrodes of the ion source [1–3]. Effusion molecular beams show very high non-homogeneity in both the longitudinal and transverse directions with respect to the molecular beam axis [4–6]. Figure 1 shows equal beam intensity lines for three lengths h (h =0, 10 R and 100 R; R – radius of the capillary) of the effusion capillary. The envelopes marked in this figure indicate the equal molecular beam intensity places. In the case, the molecular beam is formed by the effusion hole (h = 0), the intensity distribution of the effusion molecular beam is cosine shaped ($I = I_0 \cos \varphi$), whereas for longer capillaries equal beam intensity lines are evidently different [4].

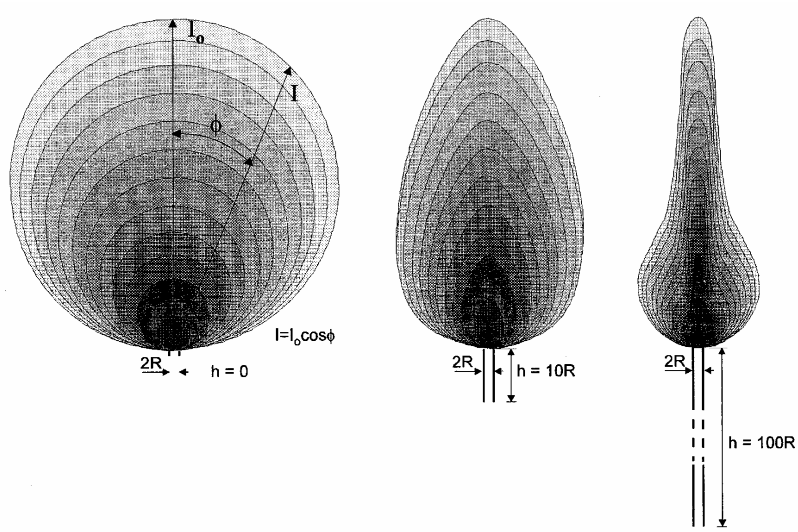

Fig. 1. Influence of the length h of the effusion capillary on the shape of the equal molecular beam intensity lines
Wpływ długości h kapilary efuzyjnej na kształt linii jednakowego natężenia wiązki molekularnej

In photoionization ion sources a non-homogenous molecular beam is intersected by a focused photon beam. The intensity of the photo-ion beam generated from this intersection is greatly affected by the position of the photon beam with respect to the capillary outlet. Two configurations of photon and molecular beams in an ion source of mass spectrometer are used, usually: (i) the photon axis is perpendicular to the effusion molecular beam axis, (ii) the axes of both beams are parallel to each other. In both cases position of the focus of the photon beam with respect to the capillary outlet can be optimized from the point of view of the number of generated ions. From this point of view the co-incident axes of effusion molecular and focused photon beam case is the best configuration [7]. For the time-of-flight mass spectrometers (TOF MS) and especially for TOF MS with reflectrons not only the ion yields but also detailed information about a place of generation of photo-ions in the ion source is very important, too. The knowledge of distribution of ions generated along the focused photon beam can be very helpful in the construction of ion sources and ion optics of time-of-flight mass spectrometers with high resolution and ion transmission coefficient. This problem was signalized by us in the previous work [8].

2. CALCULATION PROCEDURE AND RESULTS

For calculations of the number of generated ions we have applied a calculation procedure described previously [8, 9–11]. In this procedure we divide a photon beam into many elementary elements and then calculate the number of molecules effusing from an effusion capillary in each of these elements. The distribution of the number of molecules effusing from this capillary is described by analytical formula which includes the geometrical parameters (h – length, R – radius) of this capillary [12, 13]. Therefore we can calculate a concentration, n, of effusing molecules in any area of a photon beam or an average concentration of molecules in a whole photon beam. With this calculation method we can observe not only the total number of ions generated by the crossing of photon and molecular beams but also the production of ions in any area of the photon beam. These observations are very difficult or impossible in the real photon beam. By using this calculation procedure we determined distributions of ions generated along the focused photon beam intersected by an effusion molecular beam for the case where the axes of both beams are parallel to each other (Fig. 2). The unit of all parameters of the ionization system is the radius, R, of the effusion capillary. The presented results were obtained for the length of the focused photon beam $L = 100\,R$, the diameter of the photon beam before focusing $D = 20\,R$ and the wavelength of light $\lambda = 0.0002$ R.

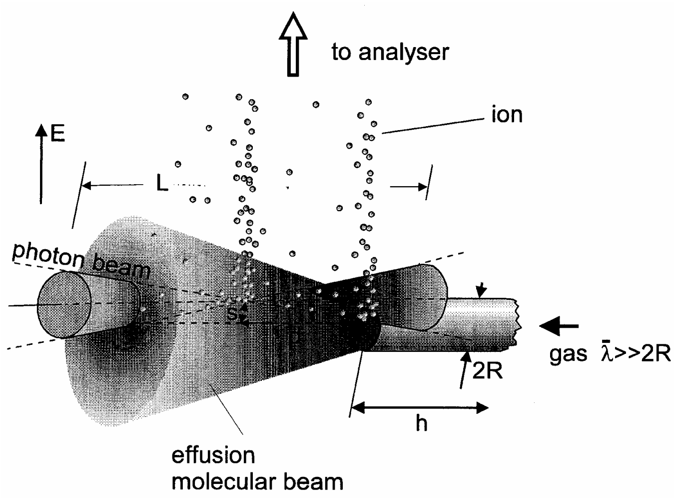

Fig. 2. Intersection of effusion molecular and focused photon beams. The axes of both beams are parallel to each other
Przecięcie efuzyjnej wiązki molekularnej i zogniskowanej wiązki fotonów. Osie obu wiązek są wzajemnie równoległe

Figure 3 shows distributions of ions generated along the focused photon beam intersected by the effusion molecular beam formed by the effusion hole ($h = 0$) for several distances d (d = -30 R, -10 R, 0, 10 R, 30 R and 50 R) between the focus and the capillary outlet and for two displacements ($s = 0$ (a) and $s = 5$ R (b)) of the capillary with respect to the axis of the photon beam. Figures 4 and 5 show similar results of calculations as in Figure 3, but in these cases the molecular beam is formed by capillaries of lengths $h = 10$ R and $h = 100$ R, respectively. The negative and positive values of the distances d in this figure mean the position of the focus of the photon beam behind and in the front of the capillary outlet, respectively (see Fig. 2).

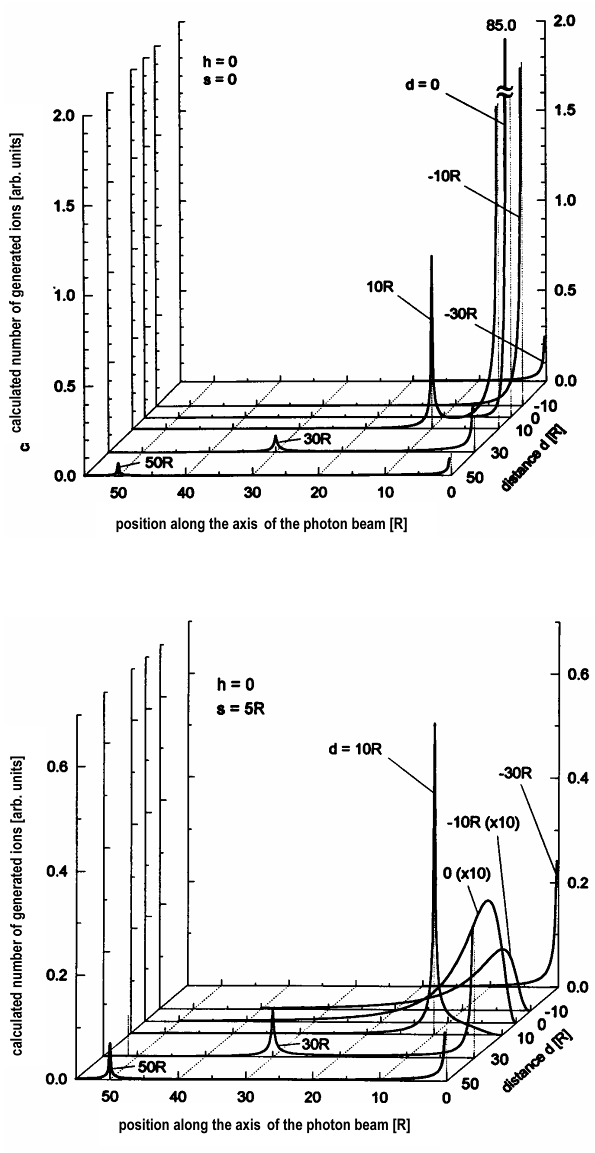

Fig. 3. The number of photo-ions generated along the focused photon beam for several distances d = -30 R, -10 R, 0, 10 R, 30 R and 50 R between the focus and the capillary outlet. The molecular beam is formed by the effusion hole (h = 0) and the displacement s = 0 (a) and 5 R (b)

Liczba fotojonów wytwarzanych wzdłuż zogniskowanej wiązki fotonów dla kilku odległości d = -30 R, -10 R, 0, 10 R, 30 R i 50 R między ogniskiem a wylotem kapilary. Wiązka molekularna jest formowana przez kapilarę (h = 0 R), a przesunięcie s = 0 (a) i 5 R (b)

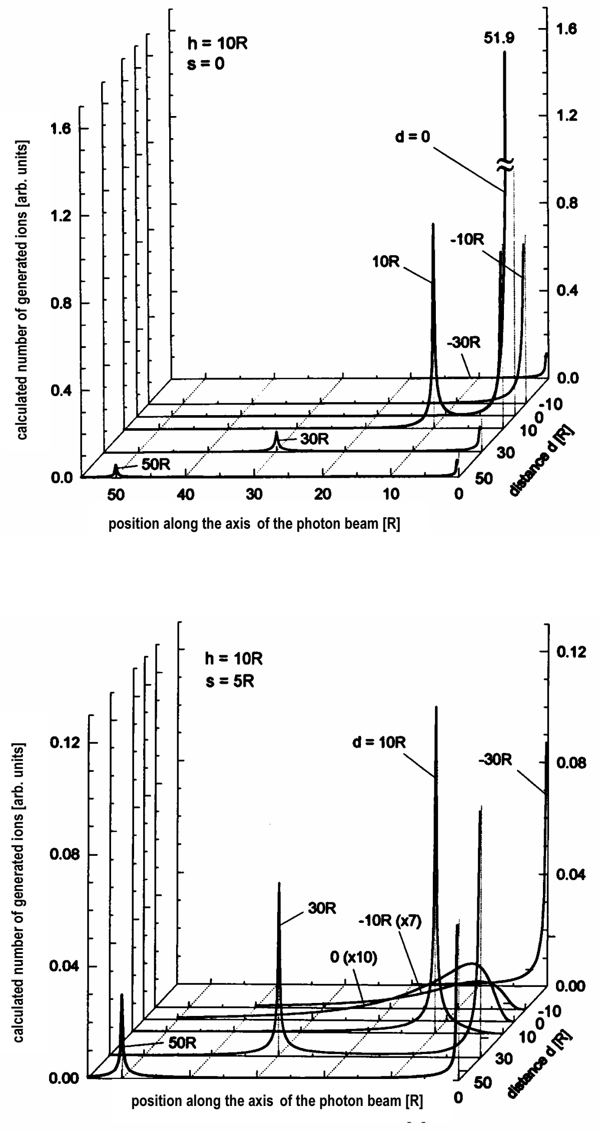

Fig. 4. The number of photo-ions generated along the focused photon beam for several distances d = -30 R, -10 R, 0, 10 R, 30 R and 50 R beween the focus and the capillary outlet. The molecular beam is formed by the capillary h = 10 R and the displacement s = 0 (a) and 5 R (b)

Liczba fotojonów wytwarzanych wzdłuż zogniskowanej wiązki fotonów dla kilku odległości d = -30 R, -10 R, 0, 10 R, 30 R i 50 R między ogniskiem a wylotem kapilary. Wiązka molekularna jest formowana przez kapilarę (h = 10 R), a przesunięcie s = 0 (a) i 5 R (b)

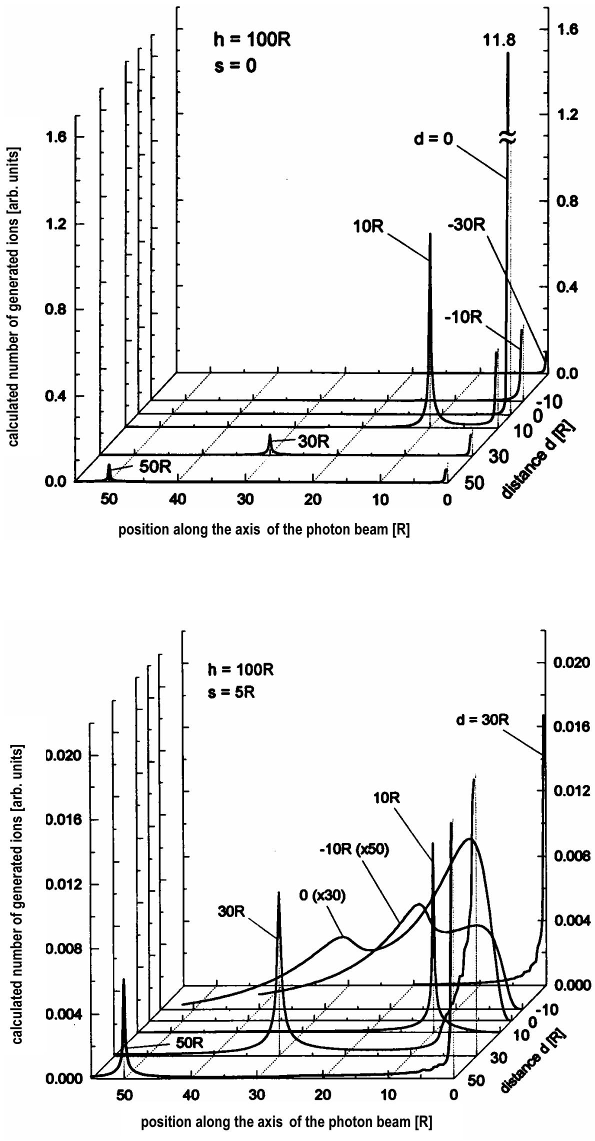

Fig. 5. The number of photo-ions generated along the focused photon beam for several distances *d* = -30 *R*, -10 *R*, 0, 10 *R*, 30 *R* and 50 *R* between the focus and the capillary outlet. The molecular beam is formed by the capillary *h* = 100 *R* and the displacement *s* = 0 (a) and 5 *R* (b)

Liczba fotojonów wytwarzanych wzdłuż zogniskowanej wiązki fotonów dla kilku odległości *d* = -30 *R*, -10 *R*, 0, 10 *R*, 30 *R* i 50 *R* między ogniskiem a wylotem kapilary. Wiązka molekularna jest formowana przez kapilarę *h* = 100 R a przesunięcie *s* = 0 (a) i 5 *R* (b).

From presented distributions of ions generated along the focused photon beam intersected by an effusion molecular beam it results that for distances $d > 0$ most of ions are produced in two areas of the photon beam, i.e. near the effusion capillary outlet (the highest density of molecules) and in the focus of the photon beam (the highest density of photons). The number of ions generated in each of these areas is adequately higher for the shorter distances d. For distance $d = 0$ the number of ions generated is the highest and they are produced near the capillary outlet (the highest density of molecules and the highest density of photons). For distances $d < 0$ the number of ions generated is adequately lower and their distribution along the photon beam results from the displacement s of the axis of the photon beam with respect to the capillary axis and from the shape of the molecular beam. For $d < 0$ and $s = 0$ the density of molecules along (beginning from the capillary outlet) the photon beam has a decreasing dependence. In these cases ions are produced near the capillary outlet, practically. For $d < 0$ and $s > 0$ ($s = 5$ R in the presented results) the density of molecules along the photon beam is in accordance with the specific equal molecular beam intensity lines dependent on the length of the capillary. In this case the distribution of ions generated along the photon beam is specific, too. These effects are explained in Figure 6.

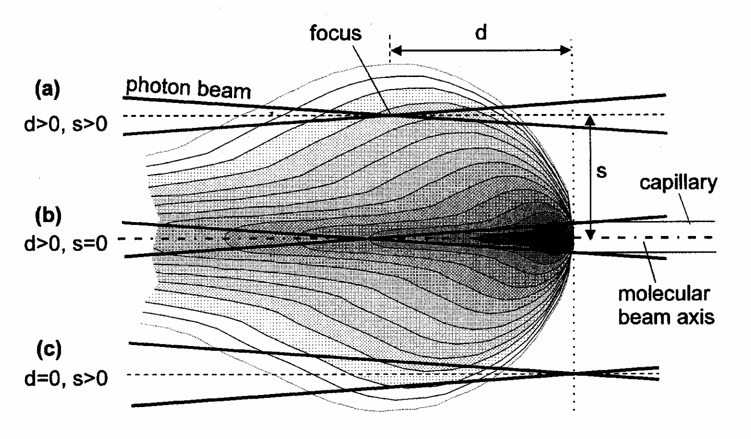

Fig. 6. Influence of the position of the focus of the photon beam (parameters d and s) with respect to the capillary outlet on the number and distribution of the generated ions
Wpływ położenia ogniska wiązki fotonów (parametry d i s) względem wylotu kapilary na liczbę i rozkład wytwarzanych jonów

The choice of the mutual configuration of effusion molecular and focused photon beams depends on the construction of the ion source and the mass spectrometer. The results presented here can be applied in other experiments utilizing the intersection these beams.

REFERENCES

[1] Boesl U., Weinkauf R., Weickhardt E. and Schlag W., *Int. J. Mass Spectrom Ion Processes*, (1994) 131, 87.

[2] Steenvoorden R.J.J.M., Kistemaker P.G., De Vries A.E., Michalak L. and Nibbering N.M.M., *Int. J. Mass Spectrom. Ion Processes*, (1991) 107, 475.

[3] Michalak L. and Steenvoorden R.J.J.M., *Acta Phys, Pol., A*, (1991) 79, 661.

[4] Adamczyk B. and Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1986) 69, 163.

[5] Michalak L. and Adamczyk B., *Int. J. Mass Spectrom. Ion Processes*, (1988) 85, 319.

[6] Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1993) 123, 107.

[7] Markowski A. and Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1997) 163, 5L.

[8] Markowski A. and Michalak L., *Vacuum* (in press).

[9] Marcinkowska E. and Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1993) 128, 157.

[10] Markowski A. and Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1996) 154, 213.

[11] Markowski A. and Michalak L., *Int. J. Mass Spectrom. Ion Processes*, (1996) 156, 141.

[12] Troicki V.S., *Zh. Tekh. Fiz*., (1962) 32, 488.

[13] Aushev W.E., Zajika N.J. and Mochnach A.W., *Zh. Tekh. Fiz*., (1982) 52, 1438.

STRESZCZENIE

Przedstawiono wyniki komputerowych obliczeń rozkładu jonów generowanych wzdłuż zogniskowanej wiązki fotonów przecinanej efuzyjną wiązką molekularną w otwartym źródle jonów spektrometru mas. Rozkład ten rozpatrzono w zależności od geometrycznych parametrów kapilary efuzyjnej, parametrów wiązki fotonów oraz jej położenia względem wylotu kapilary.