UNIWERSYTET
JAGIELLOŃSKI
W KRAKOWIE

SUPERSONIC MOLECULAR BEAM SOURCE-MODULE FOR MOLECULES CONSISTING OF HIGHLY AGGRESSIVE ELEMENTS

Molecular Laser Spectroscopy
and Quantum Information Group

T. Urbańczyk, J. Dudek, J. Koperski
M. Smoluchowski Institute of Physics, Jagiellonian University, Łojasiewicza 11, 30-348 Kraków, Poland

e-mail: joanna.b.dudek@doctoral.uj.edu.pl

Department of Photonics

WHY?

The inexpensive, widely-used and easy to mechanical machining material used in production of **molecular beam source-modules** is stainless steel. However, there exist metal elements which in melted form, due to **the high reactivity of their vapours**, lead to rapid degradation of stainless steel construction elements. Thus, manufacture of the beam source-module for those "reactive" metals requires using of materials with appropriate chemical resistance and compatibility.

Another problem is **high temperature** that has to be applied to achieve a sufficient metal-vapour partial pressure.

Zinc is subjected to both criteria of difficulty mentioned above: stainless-steel degradation while in contact with zinc vapour as well as considerably high melting point (692.7K). As 12-group metal, zinc is characterised by closed-shell electronic configuration and, along with 18-group rare gases (Rg=He, Ne, Ar, Kr, Xe), it is a good candidate to form **van der Waals** (vdW) molecules. But, due to above-mentioned experimental difficulties, vdW molecules such as Zn_2 and ZnRg have been less intensively investigated as compared with Hg_2 and Cd_2, or CdRg and HgRg.

DESIGN OF THE SOURCE

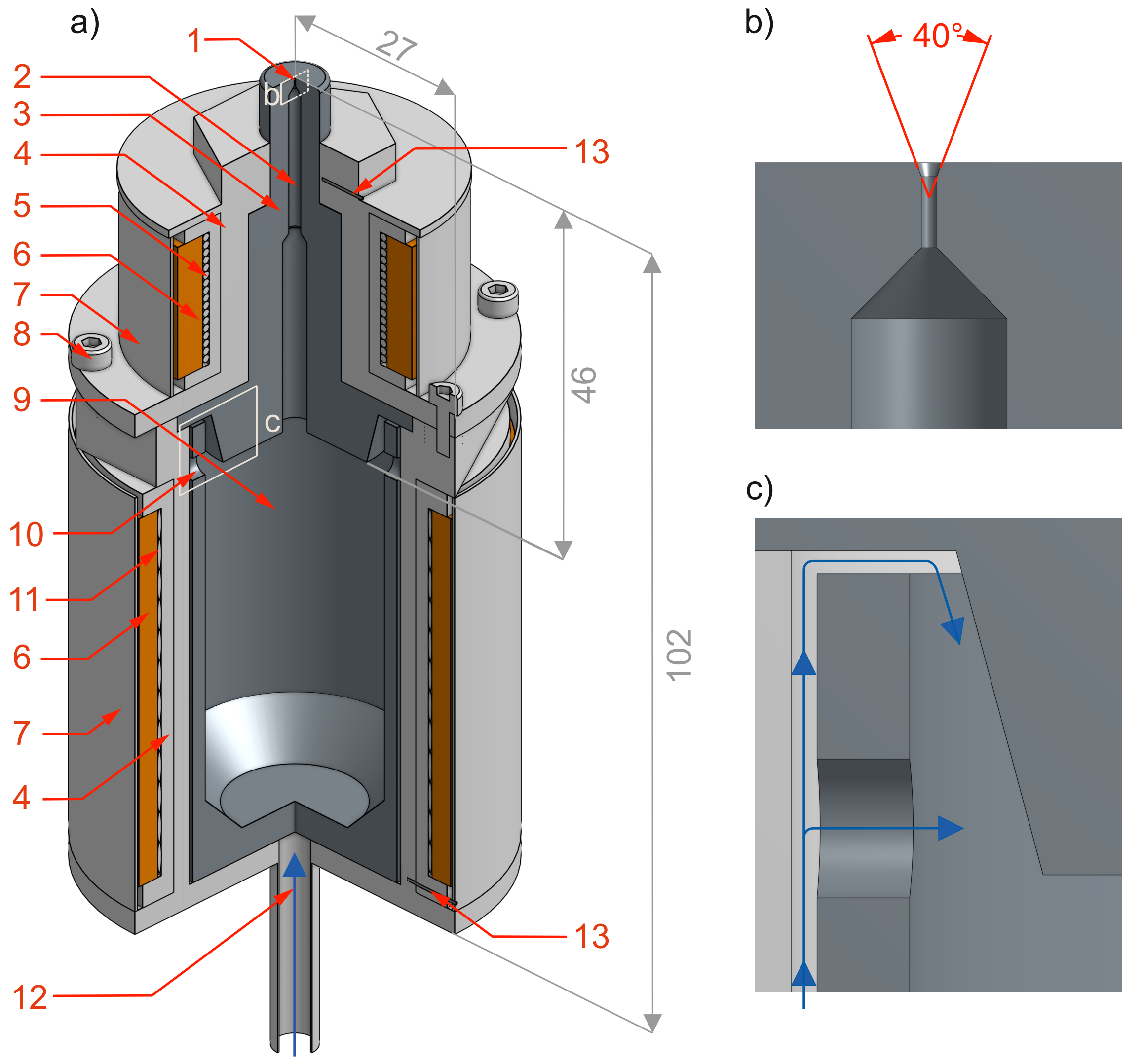

Fig.1. a) High-temperature source-module of a continuous supersonic molecular beam designed for aggressive elements.
1) Nozzle, 2) capillary passage in the nozzle-cap 3) graphite nozzle-cap, 4) stainless steel casing, 5) upper heater, 6) ceramic layer, 7) thermal shield, 8) tightening screw, 9) graphite zinc reservoir (crucible), 10) inlet-hole for the carrier-gas, 11) lower heater, 12) the carrier-gas inlet pipe, 13) thermocouples.
Insets show cross-section details of: b) the nozzle profile and c) the carrier gas inlet to the crucible (carrier gas flow marked with blue arrows).

NOVEL SOLUTIONS

The components that are exposed to molten aggressive metal, crucible and nozzle-cap (see Fig. 1), are made of **graphite** that ensures chemical resistance.

Because of inability of welding the graphite, a new method for **mixing the carrier gas and metal vapours** inside the crucible was proposed. A stainless steel inlet carrier-gas pipe is welded to the bottom of the casing. The carrier-gas fills an empty space between the casing and the crucible and then enters into the crucible through the four holes located symmetrically on the top part of the crucible wall (Fig. 1.c).

TEST OF THE SOURCE

LIF excitation spectrum of the $\mathbf{b^3 0_u^+ (4^3P_1)}, \upsilon' \leftarrow \mathbf{X^1 0_g^+ (4^1S_0)}, \upsilon''$ transitions in $\mathbf{Zn_2}$ was recorded using the new source-module. Argon as a carrier-gas at 5-bar backing pressure was delivered to the source.

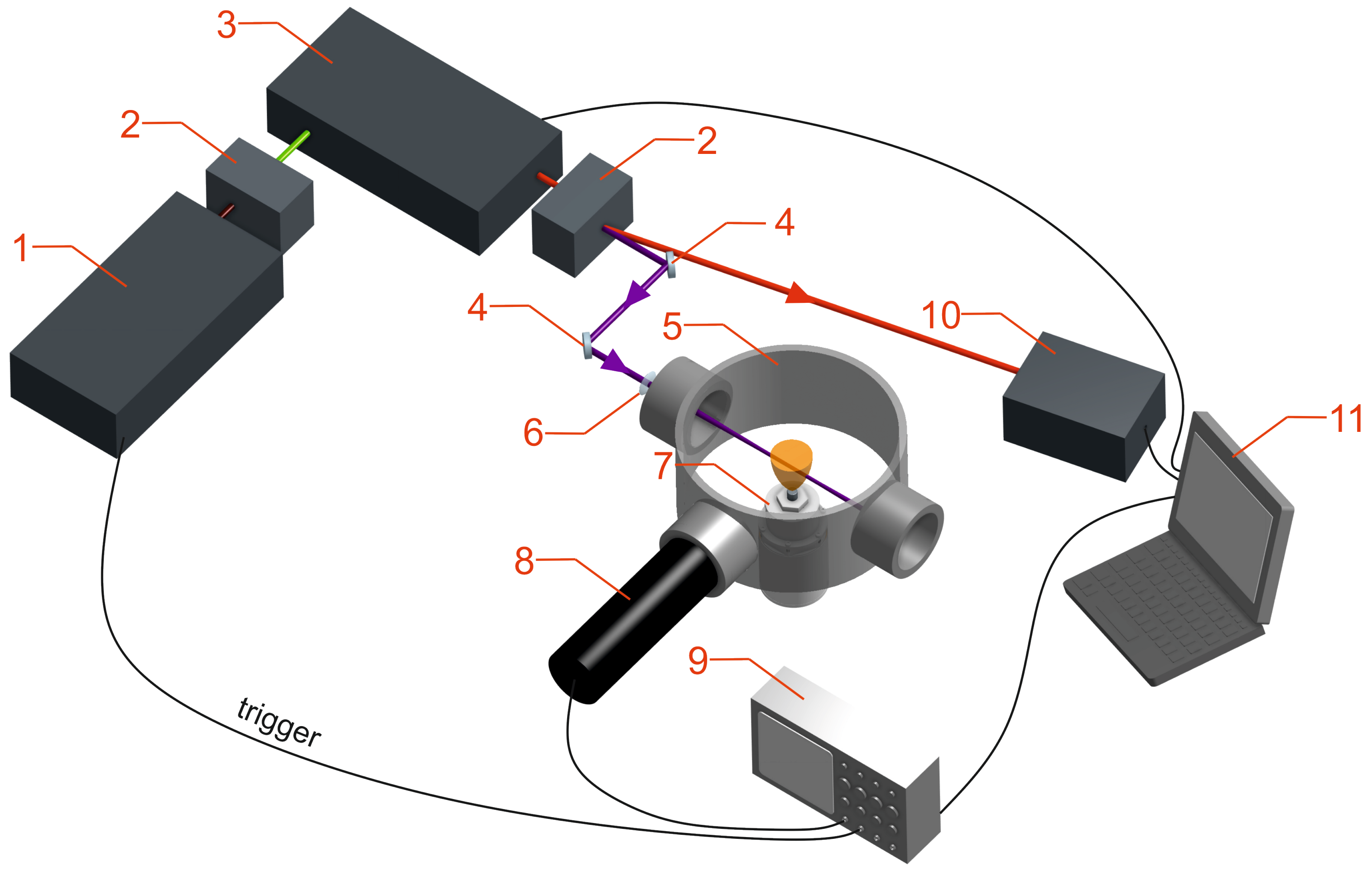

FIG. 2. Experimental set-up for LIF excitation spectroscopy of Zn_2 produced in supersonic molecular beam. 1) Nd+:YAG laser 2) second harmonic generator 3) pulsed dye laser 4) mirror 5) vacuum chamber 6) lens 7) source-module 8) photomultiplier 9) oscilloscope 10) wavemeter 11) computer.

RESULTS

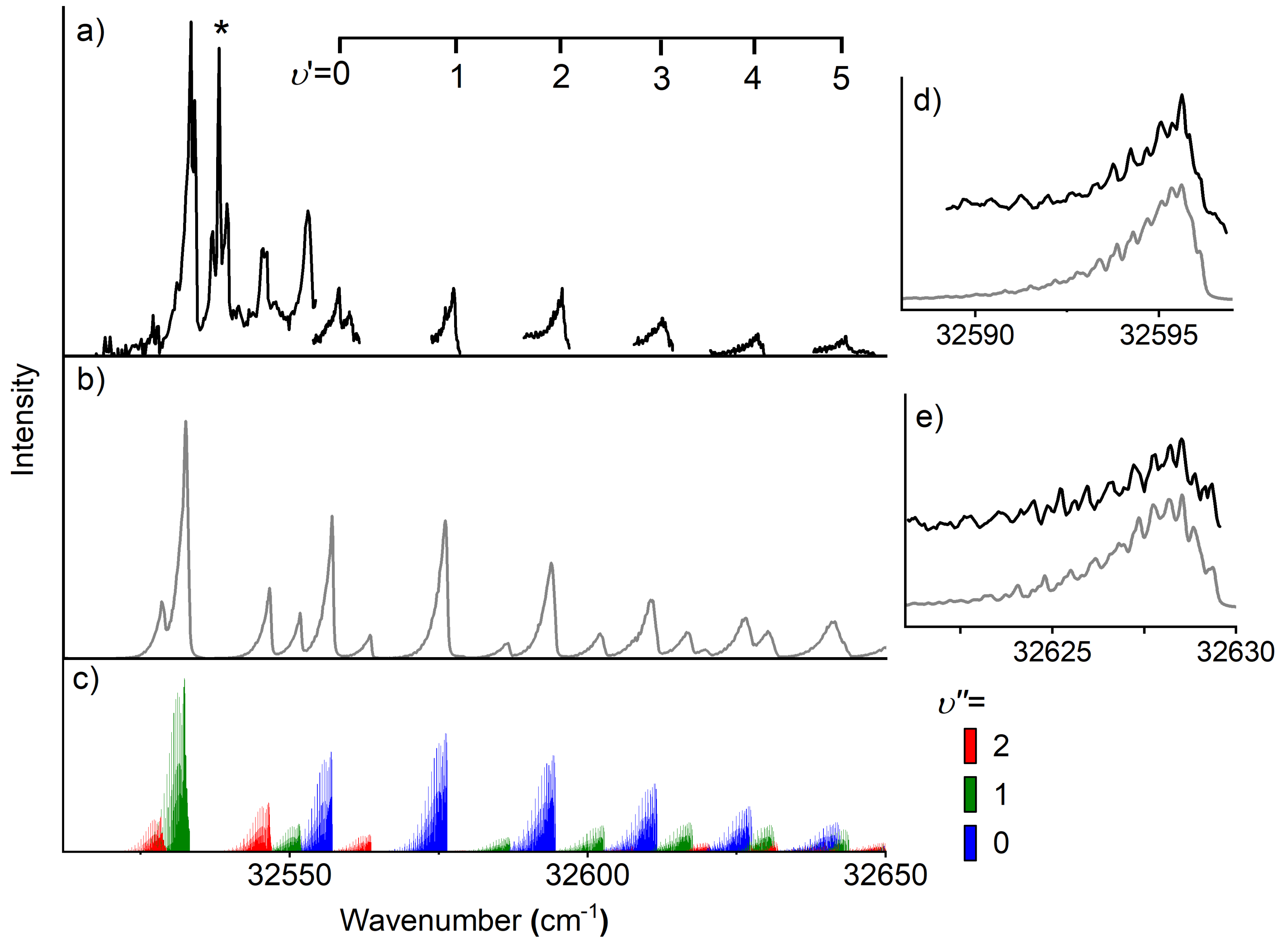

FIG. 3. a) Experimental LIF excitation spectra of the $\mathbf{b^3 0_u^+ (4^3P_1)} \leftarrow \mathbf{X^1 0_g^+ (4^1S_0)}$ transition in $\mathbf{Zn_2}$ recorded using new source-module. Unidentified line is marked with an asterisk.
b) Simulation of the $\mathbf{b^3 0_u^+ (4^3P_1)}, \upsilon' \leftarrow \mathbf{X^1 0_g^+ (4^1S_0)}, \upsilon''$ transitions with parameters: T_{vib} =150K, T_{rot}=10K, Gaussian and Lorentzian convolutions 0.1 cm^{-1}(FWHM) of rotational components, Morse-function representation for the $\mathbf{b^3 0_u^+ (4^3P_1)}$ and $\mathbf{X^1 0_g^+ (4^1S_0)}$ - state potentials c) Intensities of all individual Zn_2 isotopologue components within each of the $\upsilon' \leftarrow \upsilon''$ vibrational band (see colour legend) which constitutes the shaded profiles in b). Insets: experimental (black) and simulated (gray) rotational-isotopologue profile of d) $\upsilon'=2 \leftarrow \upsilon''=0$ and e) $=4 \leftarrow \upsilon''=0$ bands.

DETAILS ABOUT DATA ANALYSING ARE INCLUDED IN POSTER F3: *VAN DER WAALS MOLECULES CONSISTING OF AGGRESSIVE ELEMENT Zn: TOWARDS HIGH RESOLUTION.*

CONCLUSION

Operation of new high-temperature source-module of a supersonic molecular beam containing aggressive elements was tested using experiment with detection and analysis of the $\mathbf{b^3 0_u^+ (4^3P_1)} \leftarrow \mathbf{X^1 0_g^+ (4^1S_0)}$ transition in $\mathbf{Zn_2}$. The system can be applied for another reservoirs (crucibles) in source-modules of molecular-beam apparatus containing non-weldable materials.

REFERENCES

[1] J. Dudek, K. Puczka, T. Urbańczyk and J. Koperski, *High-temperature continuous molecular beam source for aggressive elements: an example of zinc*, in preparation.
[2] M. Strojecki, M. Ruszczak, M. Krośnicki, M. Łukomski, and J. Koperski, Chem. Phys. 327, 229 (2006).

ACKNOWLEDGEMENTS

NATIONAL SCIENCE CENTRE
POLAND

This project was financed by the National Science Centre Poland under contract UMO-2015/17/B/ST4/04016.