Introduction

We present a prototype of all-metal pulsed supersonic source which operates at temperatures up to 1000K and carrier gas stagnation pressures up to 8 bars. Thanks to the operation temperature much above the cadmium melting point (T_{Cd}=320K), the source can be used to produce van der Waals dimers of cadmium Cd₂ and cadmium-rare gas complexes CdRG (RG= Ar, Kr, Ne). Our pulsed supersonic source (detailed description in [1]) is part of larger experiment [2] (based on [3]) dedicated to realisation of Bohm's spin 1/2 particle version of the Einstein-Podolsky-Rosen experiment [4] for entangled ^{125}Cd atoms.

Pulsed supersonic source

In molecular beam experiments supersonic pulsed sources are preferred over those operating in continuous mode because they reduce consumption of analyzing substance and carrier gas. Moreover, pulsed sources enable using of larger nozzle diameters, higher carrier gas pressure and provide excellent conditions to work with pulsed lasers (supersonic pulse can be correlated with pulse of light). The main disadvantage of pulsed sources is that commercially available pulsed valves can operate only up to 590K, which is insufficient for many purposes (particularly for production of supersonic beam of cadmium dimers). To overcome this limitation we use long plunger attached to water-cooled commercial solenoid valve (Parker-Genval Series 9).

Principle of operation

In the experiment cadmium metal is heated in the lower reservoir (13) up to 1000K and mixed with carrier gas (Rg= Ar, Kr, Ne) delivered by lower pipe (12). Next, the cadmium vapour (partial pressure 0.2 bar) enters the upper source chamber (17) which ends with a nozzle (usually D=0.15mm orifice diameter) through which the mixture expands to the vacuum chamber forming supersonic beam containing Cd₂ and CdRG van der Waals molecules.

Tests of the pulsed supersonic source

Fig 3 LIF excitation spectra of CdAr and CdRG recorded using the B1(5P5) ←X0(5S5) and b1(5P5) ←X0(5S5) transitions, respectively. The pulsed source from Fig. 1, was employed for the production of the molecules using following parameters: a) D=0.15mm, p_{vap}=5.5bar, T_{res}=923K, T_{pul}=943K and T_{env}=943K, repetition rate f=10Hz, valve pulse width w=0.7ms, laser pulse delay t=1ms, time-gating interval 3-5us. b) D=0.25mm, p_{vap}=1.5bar, T_{res}=903K, T_{pul}=948K, T_{env}=948K, the remaining parameters as in a). c) As in a) but with time-gating interval 0.2-0.5us. d) Simulation of the bound—bound LIF excitation spectrum from a) i.e., recorded using the B1 ←X0 transition in CdAr, assuming ω_{v}=11.3cm⁻¹, ω_{u}=19.8cm⁻¹, ω_{e}=0.93cm⁻¹, R_{v}=5.01A, R_{u}=4.31A, assumed rotational temperature T_{rot}=3K, bandwidth of the laser Δv=0.2cm⁻¹ and Doppler broadening Δv=0.2cm⁻¹. e) Simulation as in d) but for n=0 and T_{rot}=19K. f) Simulation of the free—bound part of the excitation spectrum from a) assuming Born-Mayer and Morse representations for the excited and ground-state potentials, respectively. g) Sum of simulations from d) and f). h) Simulation of the bound—bound spectrum from c) but recorded using the b1 ←X0 transition in Cd₂ assuming ω_{v}=18.7cm⁻¹, ω_{u}=0.34cm⁻¹, ω_{e}=21.4cm⁻¹, ω_{u}=0.35cm⁻¹, R_{v}=4.02A, R_{u}=3.78A from previous work, as well as calculated B_{v}=0.01848cm⁻¹ and B_{u}=0.02090cm⁻¹, and assumed T_{rot}=3K, Δv=0.2cm⁻¹ and Δv=0.2cm⁻¹. i) Sum of simulations d), f) and h) plotted to reconstruct the spectrum from c).

References


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Plans for the future

Currently, we are intensively working on developing new version of the source, which will eliminate some minor disadvantages of the current prototype such as condensation of cadmium on the plunger near the water shield or difficulties associated with disassembling of the prototype for cleaning. Moreover, a new tunable pulsed alexandrite ring laser with 30MHz spectral bandwidth will be employed in spectroscopy of Cd₂ and CdRG molecules with significantly better resolution.