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Technical note

RADES an experimental set-up for the characterization of aerosol release from nuclear and radioactive materials

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ABSTRACT

An experimental set-up has been developed for the production and characterization of aerosols developed from RDDs (Radioactive Dispersion Devices, a.k.a. dirty bombs). Separate effects of temperature, materials and different atmospheres on the produced aerosols characteristics can be systematically studied. A laser heating technique is used to vaporize the sample, and aerosols are then generated mainly by nucleation/condensation of the formed vapour. Different collection systems have been developed, permitting the use of different substrates and consequently the application of different post-analysis techniques for aerosols characterization (SEM/EDX, RAMAN, ICP-MS). The set-up permits us to study the chemical processes acting in aerosol formation, thanks to the control of the experiments atmosphere and temperature. The set-up has been tested for different materials, such as ceramics, salts and metals, and proved to be feasible for the production, collection and post-analyses of aerosols. Moreover the set-up is placed in a glove box, and suitable for tests with radioactive and nuclear materials. In this paper the set-up will be described, focussing on the instrumentation applied, on the post-analysis techniques and on the experimental procedure. Finally also examples of the results obtained will be given.

1. Introduction

Evaluation of the source term (the quantitative assessment of radioactive release) is of main importance for risk assessment and emergency response in the case of accidents or sabotage involving radioactive and nuclear materials (RDEs, Radioactive Dispersion Events). Following the 9/11 terrorist attack in the U.S., an increased focus has been posed on the threat of terrorist attacks. After this event attention has been focussed on the consequences of “dirty bombs” detonation (these are bombs created by coupling a conventional explosive with highly radioactive material, a.k.a. RDDs). Studies for the estimation of doses and health consequences following dirty bombs have been conducted applying different modelling and simulation codes (Andersson et al., 2008; Apikyan et al., 2006; Magill et al., 2007; Shin & Kim, 2009). However, as also reported by Andersson et al. (2009), there are needs for better description of the source term, as these codes are highly sensitive to the input parameters. To calculate the impact on the population of a RDE the quantification of the release (total material mass and activity) and its description (size distribution, chemical composition, isotopic composition and partition)

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is necessary. In order to obtain these data and to generalize the results to different case scenarios, a deep understanding of the aerosol formation process and of the parameters influencing the aerosol characteristics is needed. In the view of this we have developed an experimental set-up with the following goals:

- the production of aerosols (from also radioactive materials) by a laser heating technique;
- the characterization of the aerosols (describing the size distribution, chemical composition and elemental partitioning);
- the study of the separate effects of different variables on the aerosol formation (e.g. materials properties, environment and temperature transients);
- understanding the chemical reactions between the gaseous precursor and the chosen environment.

The use of laser heating intends to mimic aerosols generation by dirty bomb explosions, as the vapour is formed by a rapid high temperature transient and then subject to a very sharp reduction in temperature, due to a cold gas flow. It is not intended however with our set-up to provide a complete simulation of RDDs for which large scale studies have already been performed (Harper et al., 2007; Lee et al., 2010). Laser heating has been previously applied for production of radioactive aerosols (Zanotelli et al., 1981), but in the frame of severe nuclear reactor accidents, and also for the production of metallic and ceramic particles (e.g. Leitz et al., 2011; Maio et al., 2012; Ren et al., 2013).

2. Experimental set-up

A scheme of the RADES set-up is presented in Fig. 1. This set-up fulfills the need on one hand of controlling the temperature transients by applying a controlled heating laser pulse to sample materials, on the other hand of controlling the cell experimental environment (choosing the gaseous atmosphere and pressure for each experiment); and finally it permits the collection of the aerosols for subsequent post-analyses.

2.1. Instrumentation

2.1.1. Containment vessel and laser heating

The set-up (Fig. 1) consists of a metallic spherical vessel of ca. 300 mm in diameter, used as confinement, which is closed at the bottom by a 250 mm diameter blank flange fixed with screws. The complete set-up is placed in a glove box for testing also radioactive materials. The vessel can be evacuated by a vacuum pump (BOC Edwards XDS-5) and filled with different gases. The vessel is further equipped with several (63 mm diameter) flange openings, used for windows for visual inspection. These openings are also used for the gas inlet and outlet, for the instrumentation and for the laser heating.

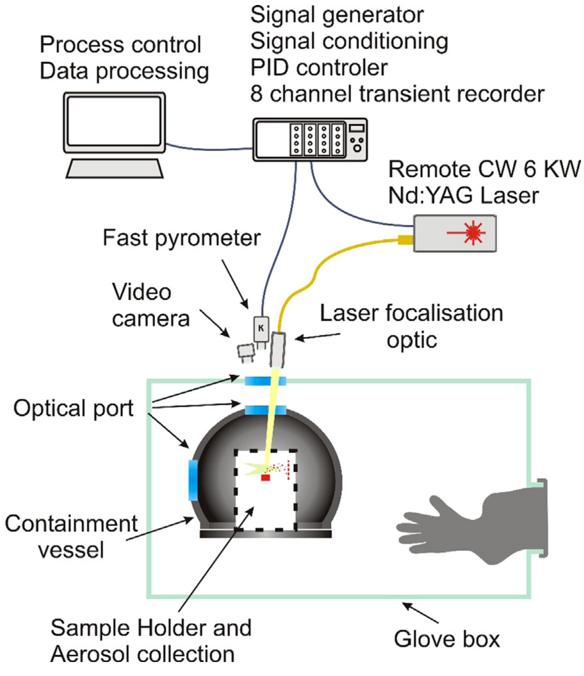

Fig. 1. A simplified scheme of the experimental set-up, showing the pyrometer and the laser optic mounted outside the gloves box, the containment vessel and the connection between the PID controller and the instrumentation. The sample holder and aerosol collection system can be changed to perform different analyses. Focus on the different collection systems is presented in the following figures.