

FIG. 1. Excitation scheme for LIF-dip spectroscopy in xenon.

## II. EXPERIMENTAL INVESTIGATIONS

In this section we present our experimental investigations on Stark effects of xenon *ns* and *nd* levels. First, the experimental arrangement is described in Sec. II A. Next, the results of the measurements are presented in Sec. II B.

### A. Experimental arrangement

The experimental arrangement consisted of a laser system for the excitation of xenon atoms to Rydberg levels, an electrode arrangement for the application of electric fields, and a detection system to monitor fluorescence light.

Stark effects in xenon were measured by probing high-lying Rydberg states by LIF-dip spectroscopy. We used a (2+1)-photon excitation scheme, shown in Fig. 1, which was similar to that used by Ebata *et al.* [18] for investigations in NO and Czarnetzki *et al.* [14] for atomic hydrogen. First, ground-state xenon atoms were excited to the  $6p[1/2]_0$  level in a two-photon transition at 249.629 nm. Subsequently, fluorescence light with a wavelength of 828.2 nm could be observed as a result of decay to the  $6s[3/2]_1$  state. A second laser was tuned to probe the transition between the intermediate  $6p[1/2]_0$  level and high-lying Rydberg *ns* and *nd* states. A resonance for such a transition was detected as a decrease of the fluorescence intensity, because part of the  $6p[1/2]_0$  level population was transferred to the Rydberg state. Therefore, when scanning the second laser and monitoring the fluorescence intensity, a transition to a Rydberg state was detected as a dip in the spectrum.

The two lasers necessary for the excitation were both tunable dye lasers, pumped by the same pulsed neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. The first dye laser was pumped by the third harmonic of the Nd:YAG laser and operated at 499.258 nm. This light was subsequently frequency doubled by a beta barium borate (BBO) crystal to create 249.629 nm photons for the two-photon transition. The second dye laser was pumped by the second harmonic output of the same Nd:YAG laser and operated at wavelengths between 580 and 630 nm.

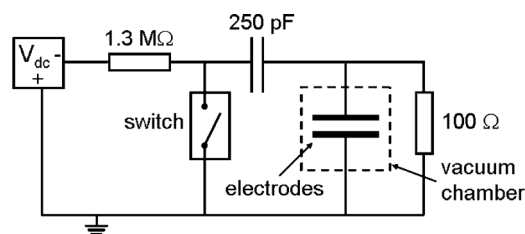


FIG. 2. Schematic diagram of the electrical arrangement for creating short voltage pulses. The high-voltage transistor switch (Behlke Electronic GmbH) could be triggered externally for synchronization purposes. The electrodes were mounted inside a vacuum chamber, creating a gap of 3 mm.

Both beams were sent to a vacuum chamber containing an electrode arrangement. The two beams were parallel to the electrode surfaces and crossed each other in between the electrodes. The energies of both lasers were reduced to a few hundred microjoules to avoid initiating a discharge and disturbing the applied electric field.

The fluorescence light was detected perpendicular to the laser beams by an intensified charge-coupled device (ICCD) camera. A lens system and an interference filter imaged the fluorescence light onto the ICCD camera, detecting only 828.2 nm light.

We applied a pulsed electric field to parallel plate electrodes, separated by 3 mm, in xenon gas at 50 Pa. The field was pulsed to prevent the formation of a discharge for voltages above the breakdown voltage of the system. Using the electrical scheme shown in Fig. 2, we could apply voltage pulses with a full width at half maximum of about 50 ns and an amplitude of up to 1.5 kV. In this way, the electric field in the gap was controllable and uniform.

Finally, the lasers, the ICCD camera and the voltage pulse were synchronized with a delay generator.

### B. Experimental results

#### 1. Stark effects for *nd* levels

We investigated Stark effects for  $nd[3/2]_1$  levels with principal quantum numbers  $n=12-15$  and  $n=18$ . Figure 3 shows fluorescence-dip spectra for the transition to  $15d[3/2]_1$  in different electric fields. It is clear that the dip at 586.51 nm, corresponding to the  $15d[3/2]_1$  level, moves to longer wavelengths for increasing electric fields. Additionally, for an electric field of 2100 V/cm, we observe extra dips at wavelengths 586.40 and 586.28 nm. These dips correspond to transitions to  $13f$  levels which are forbidden without an electric field, but become allowed when they are mixed with other levels in high electric fields.

The shifts of  $nd[3/2]_1$  levels in electric field for principal quantum numbers  $n=12-15$ , and  $n=18$  are shown in Fig. 4. For applied electric fields between 0 and 4000 V/cm, we measured Stark shifts of up to  $4.8 \text{ cm}^{-1}$ . The measurements show that the observed shift is higher for larger principal quantum numbers, as expected.

#### 2. Stark effects for *ns* levels

The shifts of  $ns[3/2]_1$  levels in electric fields for principal quantum numbers  $n=14-16$  are shown in Fig. 5. Applying