L.6: Change in pulse-shape of Optogalvanic signal due to Penning Ionization

The temporal evolution of the optogalvanic (OG) signals was studied and a change in the pulse-shape of the OG signals was observed at lower discharge currents at Laser Systems Engineering Division of RRCAT. A homemade dye laser, pumped by a homemade copper vapor laser, irradiated the discharge of a Zr-Ne hollow-cathode lamp. An OG signal was observed at 588.2 nm due to resonant absorption of laser photons corresponding to a transition, $3s[3/2]_2$ $3p\,[1/2]_1$, of Ne. At higher discharge currents (10 mA), the pulse-shape of the OG signal was similar to that reported in literature, however at lower discharge currents (5 mA) new features in the pulse-shapes were observed, Fig. L.6.1. When the discharge current decreased from 12 to 03 mA, a distinct second peak appeared between 20-40 s in the positive part of the OG signal at a discharge current of 5 mA. The amplitude of the second positive peak became comparable to the first positive peak and the two peaks started merging when the discharge current was further lowered down.

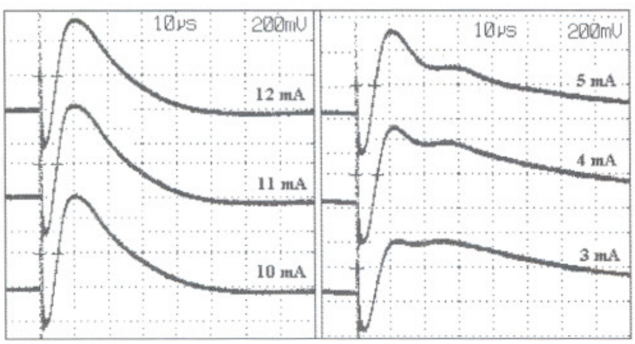

Fig. L.6.1: Pulse- shapes of OG signals at 588.2nm

It was found that the change in pulse-shapes of the OG signals was due to the Penning ionization, which dominates over electron impact ionization at lower discharge currents (5 mA) due to low vapor pressure of Zr atoms. The collisional energy transfer takes place between excited $Ne(3s[3/2]_2)$ atoms and $Zr(^3F_3$ and $^3F^4)$ atoms by the following Penning ionization processes:

$$Ne^* \,(3s[3/2]_2) + Zr\,(^3F_4) \rightarrow Ne\,(^1S_0) + Zr^{+*}\,(e\ ^4H_{11/2}) + e^- + \Delta E\,(+10\,cm^{-1}) \quad -- \quad (1)$$

$$Ne^* \,(3s[3/2]_2) + Zr\,(^3F_3) \rightarrow Ne(^1S_0) + Zr^{+*}\,(e\ ^4H_{7/2}) + e^- + E\,(-41\,cm^{-1}) \quad -- \quad (2)$$

where energy defect, E (+10,- 41 cm^{-1}), is within thermal energy kT. The relevant energy levels of Ne and Zr, which are required to explain the Penning ionization process in the Zr-Ne mixture discharge are shown in Fig. L.6.2.

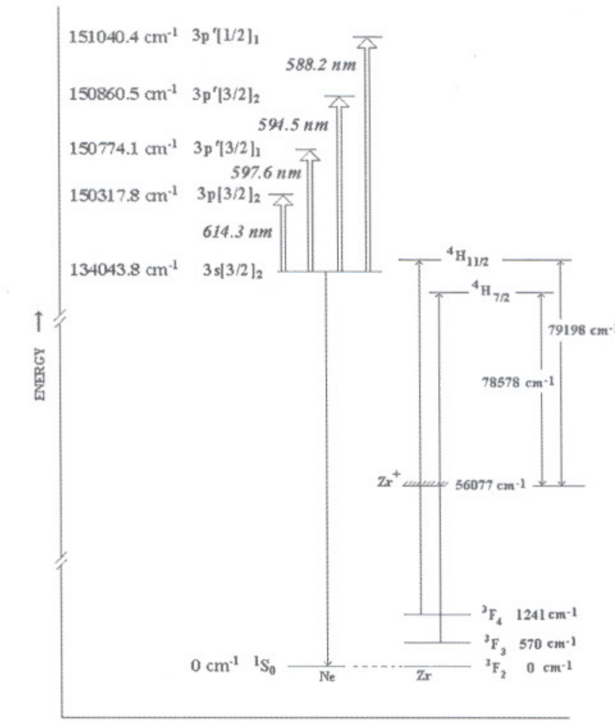

Fig.L.6.2: Partial energy level diagram for the relevant Zr, and Ne atomic levels.

The resonant absorption of laser photons of 588.2 nm, excited the metastable Ne population at $3s[3/2]_2$ level to $3p\,[1/2]_1$ level and thus those Ne atoms, which otherwise were ionizing the Zr atoms by Penning ionization were not available. A reduction of metastable Ne population at $3s[3/2]_2$ level reduced Penning ionization and ion density of Zr^+. The laser excited Ne level, $3p\,[1/2]_1$ (151040.4 cm^{-1}) lies much above Zr^{++} (113175 cm^{-1}) and thus it is inefficient in ionizing Zr. Consequently the impedance of the discharge increased and voltage drop across the hollow-cathode increased, which led to appearance of a second peak in the positive part of the OG signal. The disappearance of the double humped feature in the temporal profile of the OG signals at higher discharge currents (≥ 10 mA) indicates that the Penning contribution becomes negligible and electron-impact ionization becomes dominant. Similar behavior of temporal evolutions of the OG signals, observed at 594.5, 597.6 and 614.3 nm, were also studied [*R. Khare et al., Optics Communications, 283, 542 46, (2010)*].

Reported by:
R. Khare (rkhare@rrcat.gov.in),
V. K. Saini and V. K Shrivastava