A new system containing small crystals of aluminum oxide doped with carbon (Al2O3:C) attached to optical fiber cables has recently been introduced. During irradiation, the system monitors the radioluminescence (RL) from the crystals and after irradiation, an optically stimulated luminescence (OSL) signal can be read out by stimulating the crystal with light. This thesis applies the initial part and the total area of the resulting OSL decay curve for dosimetry measurements and investigates the effects of temperature and proton energy, i.e. ionization density, on the RL and OSL signals from Al2O3:C. In the temperature study, it was found that the OSL signal depends on both irradiation and stimulation temperature while the RL signal is effected only by the irradiation temperature. The initial OSL signal is increasing with temperature whereas the total OSL area is decreasing. Therefore, if the irradiation temperature is kept constant, one can find an integration time which provides an OSL signal independent of stimulation temperature. Overall, the RL and OSL signals vary between -0.2 to 0.6% per C. Thermal effects were simulated with a band structure model and indicated that the temperature effects are caused by the combined efforts of energetic shallow traps and thermal excitation from intermediate states in deeper traps. In the study of ionization density, we investigated protons with energies between 10 and 60 MeV (4.57 to 1.08 keV/μm in water). Experimentally, we observed that the initial OSL signal provided a signal independent of linear energy transfer (LET) for all energies at 0.3 Gy. The total OSL area showed an LET dependent behavior at all doses and energies. We used track structure theory (TST) to give possible explanations for the LET dependence of the OSL signal. From these calculations, we found that the initial OSL signal is, in general, not LET independent which makes Al2O3:C unsuitable for OSL proton dosimetry. The initial OSL signal can, however, be combined with the total OSL signal to provide an LET independent response for a given dose and LET interval. On the basis of TST, we estimate a so-called “target radius” to be between 30 and 150 nm and associated this radius with a charge migration distance in the crystal.