Photocathodes and DC Guns for Next Generation Light Sources

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A new class of synchrotron light sources, based on the use of superconducting electron linear accelerators and beam recirculation with energy recovery, is currently under active consideration. The injectors for such accelerators must deliver high brightness electron beams with appropriate RF time structure and the full average beam current. Various photoemission cathodes have been demonstrated to produce high brightness electron beams, suitable high frequency RF time structure, and high average current, and thus are a natural choice for this application. Such cathodes may be used in either DC or RF electron gun structures. The technical challenge is to develop a photoemission electron source which satisfies all the electron beam requirements simultaneously, and which offers an acceptable operational lifetime.

To support delivery of the high average beam current required by these light sources, typically 100 mA or more, a high photocathode quantum efficiency is necessary. There are three families of high quantum efficiency photocathodes – the alkali antimonides, the alkali tellurides, and the negative electron affinity (NEA) III-V semiconductors. All of these photocathode families require an excellent vacuum environment to obtain high quantum efficiency and long operational life. Certain NEA semiconductor cathodes offer the significant additional advantage of a very small thermal emittance.

We will describe the operational characteristics of GaAs NEA photoemission cathodes in high voltage DC electron guns at Jefferson Laboratory. The 1/e operational lifetime of these cathodes exceeds $10^5$ coulombs/cm$^2$, and is limited only by ion back bombardment. Compared with RF guns, DC gun structures offer straightforward paths to improved vacuum, and thus reduced ion back bombardment. Recent ion implantation developments have allowed the operation of large area electrodes at DC fields as high as 30 MV/m with extremely low field emission, making DC guns very competitive with RF guns from the standpoint of cathode field strength [1]. Finally, lasers providing the necessary high frequency optical pulse trains at the proper wavelength for use with NEA GaAs cathodes have been demonstrated [2]. Taken together, these developments indicate that an electron injector for these new light sources, based on an NEA photocathode and a DC electron gun, can be developed.

References


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