CC/NUMBER 40
OCTOBER 5, 1981

This Week's Citation Classic

Penner S. Calculations of properties of magnetic deflection systems. Rev. Sci. Instr. 32:150-60, 1961. [National Bureau of Standards, Washington, DC]

A convenient matrix method (or calculating properties of magnetic deflection systems is presented. This method is applicable to particle beams of small spatial and angular extent, and small energy spread. Equations for quadrupole lenses and for deflecting magnets are given. Examples are given to show the procedure for calculating the parameters of magnet systems. [The SCI® indicates that this paper has been cited over 130 times since 1961.]

Samuel Penner
Center for Radiation Research
National Bureau of Standards
Washington, DC 20234

August 14, 1981

"In 1959, the National Bureau of Standards (NBS) began an expanded program in nuclear and radiation physics, based on a new 150 MeV electron linear accelerator (LINAC). To make optimum use of the LINAC, it was necessary to design a facility with multiple target areas, requiring complex beam transport systems to guide the electron beams to the various targets, select an appropriate energy spread, and focus the beam on the targets. No one on the NBS staff at that time had any experience in the design and use of beam transport systems for particle beams. My division chief at the time, H.W. Koch, assigned me the task of learning beam transport technology and designing the required systems, working in conjunction with J.E. Leiss, who had primary responsibility for the LINAC and facility design.

"My study of the meager literature on the subject which existed at the time revealed that although high performance beam transport systems were in use in many laboratories, there were no widely recognized, general purpose computational methods for designing and optimizing systems for particular applications. From W. Chinowsky of Brookhaven, I learned the use of 2 x 2 transfer matrices to calculate the first-ordér behavior of quadrupole focusing channels. From K.L. Brown of Stanford University, I learned the use of dipole magnets to disperse the beam, select a desired momentum interval, and recombine the beam nondispersively. I then put the optics of dipole magnets into the same matrix formalism as was used for quadrupoles and extended the matrix formalism to three dimensions to include the first-order effect of momentum deviation on the particle orbits.

"At first, I collected my results in a set of notes for my own use in designing the transport systems for the NBS LINAC, and then expanded these notes as an internal report so that my colleagues could understand what I was doing and, hopefully, help in the design of the systems. I had no intention of formally publishing this work until Koch urged me to do so, since it contained little original material. I was therefore somewhat surprised by the large number of requests for reprints that began to come in shortly after the publication of the paper in February 1961, and by the cash award I re ceived from NBS for authoring this paper. In retrospect, the value of the paper lies largely in its utility and convenience in the design of complex systems.

"It remained for other workers in the field to expand the matrix formalism to six dimensions in order to include simultaneously both transverse planes, the time (or phase) coordinate of the particles, and the relative momentum, and to add the lowest order nonlinear corrections to the linear transport theory.[1] The theory has been incorporated in a general purpose computer program, 'TRANSPORT,' which is widely used for particle beam transport system design and optimization."[2]

1. Brown K L. A first- and second-order matrix theory for the design of beam transport systems and charged particle spectrometers. Advan. Particle Phys. 1:71-134, 1967.
2. Brown K L, Carey D C, Iselin C & Rothacker F. TRANSPORT: a computer program for designing charged particle beam transport systems. Stanford, CA: Stanford Linear Accelerator Center, February 1974, SLAC-91, Revision 1.