Crossed-Field Research in Universities

Y. Y. Lau
Department of Nuclear Engineering and Radiological Sciences, and Applied Physics Program University of Michigan Ann Arbor, MI 48109-2104

Tel: (313)764-5122 FAX: (313)763-4540 email: yylau@engin.umich.edu

The important functions of a university include generating new knowledge, preserving old knowledge, and helping students learn their own ways of looking into a problem. The natural questions are: How does crossed-field device (CFD) research fit in a university setting and how can such research be coordinated with and have an impact on industrial R&D activities?

First recall that a collection of charged particles in an external magnetic field will invariably experience a crossed electric and magnetic field in some region. Even in the case of a neutral plasma, that region is at the boundary, where the sheath is formed. Yet, in spite of such generality, it has always been a challenge in the academic community to conduct research on electron dynamics in a crossed-field in general and on a specific CFD in particular.

It seems to me that it is relatively easy to generate new knowledge when one works on CFD. The main reason is that the subject matter is rich in unexplained phenomena while the research community is sparsely populated. The subject is known to be difficult [1]. There are lots of things that we do not comprehend even at the fundamental level. For example, though crossed-field devices are generally much noisier than linear beam tubes, the basic mechanisms responsible for noise generation remain obscure, more than 70 years after the invention of the first (Hull) magnetron. Basic research, in which universities excel, may finally provide the clues needed to make real progress in this area.

One relevant and fundamental example is provided by the startling discovery made recently by my student, Peggy Christenson, that cycloidal electron flows in a crossed-field gap are violently unstable when a very small AC voltage is imposed across the gap (which is planar and does not have any circuit element) [2]. This astounding result was discovered after this CFD Workshop was convened. Even more recently, upon the suggestions of Dave Chernin, Christenson found that a small resistive load would destabilize such cycloidal flows even in the absence of an rf signal, and this work is still ongoing [3]. The above-mentioned instabilities, modulational or resistive, are electrostatic and one dimensional — so they are the most fundamental. They have never been suspected in the past since the more familiar diocotron and magnetron instabilities are necessarily two-dimensional in nature. These recent discoveries are likely to be one of the many reasons behind Pierce's statements on CFD [I], and we haven't even gone off the ground to venture into the two dimensional analog of these new instabilities.

Another reason that progress can now be made more readily in CFD studies is the availability of a number of very powerful particle codes/ as evident from the papers given in this Workshop. This is a distinct, perhaps decisive, advantage we now have which was absent in the late 1950's or 1960's. What is wanting is the dedication of the young generation to learn and to research/ with passion. The subject is difficult but it is also fun to work on.

There are obstacles, however. Foremost is the perception and the general lack of interest. The challenge is particularly acute for crossed-field devices. If rf vacuum electronic devices are as "endangered" as the spotted owl, CFD is the most vulnerable among all. For example, the most notable DoD university programs, MURI and ATRI, have only a minimal effort in crossed-field devices. The research activities in these programs have been mainly on linear tubes such as TWT, klystron, free electron laser, gyrotron, cerenkov radiatior, virtual cathode oscillator, and others. Northeastern University (Professor Chung Chan's group) is the only university in the US that has experiments dedicated to CFD noise. Likewise, no national lab or government lab seems to have a significant component in crossed-field research either. Given such a "cultural" bias, it is very difficult to sustain a serious effort in CFD research, or for long. The vicious cycle — lack of serious interest in CFD erodes support which in turn results in further lack of interest — must be broken. Given the fact that CFD's are widely used, and that there are many, many good research topics, it is hard for me to accept that CFD works will disappear in a Darwinian fashion. The danger is real, and the precious knowledge base may soon be lost forever.

Another issue is that much of the CFD work is conducted with an interest in national security. In many universities, in particular in their engineering schools, many students who are technically qualified to perform research are foreign students. Already facing many challenges being foreign students, the last thing they or their professors want is to work on a project that provides additional hurdle (real or imagined) just because of their citizenship status.

Finally, I should add that jumping into a subject simply because it is currently fashionable usually is a kiss of death for a researcher. We don't have this problem working on CFD.

[1] J. R. Pierce, 1994, as quoted in Saloom's paper on p. 2 of these Proceedings.

[2] P. J. Christenson and Y. Y. Lau, "A New Modulational Instability in a Crossed-Field Gap", to be presented at the IEEE Int'l Conference on Plasma Sciences, (Boston, MA, June, 1996); submitted to Phys. Rev. Lett.

[3] D. Chernin, P. J. Christenson, and Y. Y. Lau, "A New Resistive Instability in a Crossed-Field Gap", to be presented at the IEEE Int'l Conference on Plasma Sciences, (Boston, MA, June, 1996).