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During the past year, we have made progress on frequey shifting by means of plasmas. Theoretically we have demonstrated that a rising plasma density tends to slow down and trap microwaves passing through the plasma-filled region. This increases the interaction time, so that a very rapid rise in plasma density is not required to produce very high frequency shifts. A pliminary version has been submitted to the Transactions of Plasma Science, and more updated version is in progress. An attempt to provide frequency upshifts by use fo multiple transverse arcs was attempted without the use of equalizing resistors. The plasma discharge was observed, and the frequency upshift was seen, as was expected but it was not as extensive as in previous systems. A more balance system is being developed.

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FINAL REPORT

to the

Air Force Office of Scientific Research

Introduction

During the past year, we have made progress on frequency shifting by means of plasmas. Theoretically we have demonstrated that a rising plasma density tends to slow down and trap microwaves passing through the plasma-filled region. This increases the interaction time, so that a very rapid rise in plasma density is not required to produce very high frequency shifts. A preliminary version has been submitted to the Transactions on Plasma Science, and a more updated version is in progress.

An attempt to provide frequency upshifts by use of multiple transverse arcs was attempted without the use of equalizing resistors. The plasma discharge was observed, and the frequency upshift was seen, as was expected but it was not as extensive as in previous systems. A more balanced system is being developed.

An interface code to simplify the use of the simulation "MAGIC" has been developed and run. This is a simple preliminary version, however.

Two papers were written during this past funding year. One of thes papers has been accepted with the other pending. One paper is on the theory and experimental aspects of frequency shifting by plasma jets and changing plasma density. One is on ball lightning,

using new experimental evidence obtained from approximately 100 ultra-high voltage sparks in the Oak Ridge 25 MV tandem electrostatic accelerator. This paper has been accepted.

Three papers were presented in the November meeting of The American Physical Society in Tampa, Florida. One paper was on Frequency Shifting, one was on Bohm Diffusion via MHD, and one was on Computer Simulation of Orbitron Operation using MAGIC.

A visit to the laboratory of Spencer Quo and a colloquium were given at the Polytechnic University of New York.

A visit to India (at their expense) was made to set up a joint program in plasma education and industrial plasma processing. This was to the Birla Institute of Technology, Ranchi (Bihar State), India.

A cold fusion experiment was attempted. The idea was to impregnate a Pd rod with D. Then, by cooling the rod to 4° K (Liquid Helium), the crystal lattice should stop thermally vibrating, and tunnelling from one D site to another might occur. Two trials were made with negative results. Two calibrated neutron counters and a Geiger counter were used. (One begins to become interested in U^{235} reactors).

Studies of advanced plasma sources using chemically-driven devices were initiated. Also, rf and Orbitron sources were sketched up for future use. In general, this has been a time of change and redevelopment.

Three papers were submitted to the IEEE COPS meeting and will be given during the next funding year. These papers include One on magnetohydrodynamics, one on the simulation of frequency shifting using MAGIC, and one on ball lightning.

A-1

New initiatives started during this funding period include the simulation of frequency shifting using MAGIC.

Simulation Code Development

As an aid to our work using the MAGIC pic code, it was decided to write a translator code to take the raw MAGIC data dumps and translate them into something usable by other 3D graphics codes. This will allow us greater flexibility in the display of the information supplied by MAGIC and reduce the number of data runs required in running the MAGIC code.

New features in the display code we have chosen, Delta Graph Pro, will also allow us to display the data in real space coordinates as opposed to evenly spaced grids, as is now implimented in MAGIC and the translator code. The translator code, as yet unnamed, at this point in time takes the raw data dumps for 3D plots only and translates them into a form used by most spread sheets and data processing routines. Included in the section below is a copy of the translator code. This code is written in basic.

Translation Code

```
DIM MAT$(100,100)
PRINT "INPUT FILE FOR TRANSLATION"
INPUT INFILE$
CALL COUNT(INFILE$,Z)
CALL TRANSLATE(INFILE$,RO,COL,Z)
END

SUB COUNT(INFILE$,Z)
LET Z = 0
OPEN #7 : NAME INFILE$ , ORGANIZATION TEXT
LET LOOK$ = " $DMP$DMP$DMP$DMPSTARTBLOCK     "
DO WHILE MORE #7
LINE INPUT #7 : CHK$
IF CHK$ = LOOK$ THEN
LET Z = Z + 1
```

```
END IF
LOOP
END SUB




SUB NEWNAME(INFILE$,OUTFILE$,Q)
OPEN #5 :NAME "TEMP" , ORGANIZATION BYTE, CREATE NEW
LET A1$ = ".DAT"
LET B1$ = STR$(Q)
WRITE #5 : INFILE$
WRITE #5 : A1$
WRITE #5 : B1$
WRITE #5 : CHR$(013)
CLOSE #5
OPEN #6 : NAME "TEMP" , ORGANIZATION TEXT
LINE INPUT #6 : OUTFILE$
CLOSE #6
UNSAVE "TEMP"
END SUB




SUB TRANSLATE(INFILE$,RO,COL,Z)
OPEN #1 : NAME INFILE$ , ORGANIZATION BYTE
FOR Q = 1 TO Z
CALL NEWNAME(INFILE$,OUTFILE$,Q)
OPEN #2 : NAME OUTFILE$, ORGANIZATION BYTE, CREATE NEW
LET DUM1$ = "1"
LET I = 1
DO UNTIL DUM1$ = "$"
READ #1 , BYTES 1 : DUM1$
LOOP
DO UNTIL I = 9
READ #1 , BYTES 1 : A$
IF A$ = " " THEN
LET I = I + 1
IF I = 9 THEN
READ #1, BYTES 2 : ROW$
 IF Q > 1 THEN
PRINT ROW$
END IF
IF ROW$ = "  " THEN
LET I = 0
```

```
                    ELSE
                    PRINT ROW$
                    LET RO = VAL(ROW$)
                    END IF
                    END IF
                    ELSE
                    LET I = 0
                    END IF
                    LOOP
                    LET N = 1
                    READ #1, BYTES 2: DUM$
                    LET COUNT = 1
                    DO UNTIL COUNT = (RO+1)
                    LET BYTE = 14
                    FOR K = 1 TO BYTE
                    READ #1 , BYTES 1 : DUM2$
                    IF DUM2$ = CHR$(013) THEN
                    READ #1, BYTES 2 : DUM1$
                    ELSE
                    LET N = 0
                    END IF
                    NEXT K
                    LET COUNT = COUNT + 1
                    LOOP
                    READ #1 , BYTES 10 : DUM1$
                    READ #1 , BYTES 2 : COLL$
                    PRINT COLL$
                    LET COL = VAL(COLL$)
                    READ #1, BYTES 2: DUM$
                    FOR M = 1 TO COL
                    LET BYTE = 14
                    FOR K = 1 TO BYTE
                    READ #1 , BYTES 1 : DUM2$
                    IF DUM2$ = CHR$(013) THEN
                    READ #1, BYTES 2 : DUM1$
                    ELSE
                    LET N = N
                    END IF
                    NEXT K
                    NEXT M
                    READ #1, BYTES 2. DUM$
                    FOR M = 1 TO COL
                    LET COUNT = 1
```

```
DO UNTIL COUNT = (RO+1)
LET BYTE = 14
FOR K = 1 TO BYTE
READ #1 , BYTES 1 : DUM2$
IF DUM2$ = CHR$(013) THEN
READ #1, BYTES 2 : DUM1$
ELSE
WRITE #2 : DUM2$
END IF
NEXT K
IF COUNT = RO THEN
WRITE #2 : CHR$(013)
ELSE
WRITE #2 : ", "
END IF
LET COUNT = COUNT + 1
LOOP
NEXT M
CLOSE #2
NEXT Q
CLOSE #1
END SUB
```

Summary of India Trip

June 6 - June 22, 1991

My trip to India was funded entirely by the Birla Institute of Technology, Ranchi (Bihar State). The trip was instigated by Professor Dikshitulu Kalluri, formerly of Birla, but at present Professor of Electrical Engineering at the University of Lowell, Lowell, Massachusetts 01854. I met Professor Kalluri at an IEEE Plasma meeting. He does frequency modulation in pulsed plasmas, as I do. Professor Kalluri also travelled to India with me.

The object of me trip was to develop interest in plasma engineering at the Birla Institute of Technology. The Birla Institute of Technology is a private institute, founded by the very wealthy

Birla family. The Birla family obtained their wealth by industrial development. Most of the automobiles in India are Birla products, for example. A comparable Indian family would be the Tatas. The university is extremely highly regarded, and has approximately 100 applicants for every student position. It is situated on an enormous estate outside Ranchi.

In addition to the university, the site contains an industrial start-up complex, where students of an entrepreneurial bent can try to build up their own companies with Birla support and help. I toured this complex, and found several exceedingly successful businesses operating, including an automatic coal-feeder for furnaces and control panels for large-scale electrical mining equipment.

At the Birla Institute of Technology, I gave a comprehensive set of lectures on Plasma Engineering. Professor Kalluri did also. My lectures were difficult, in that while I flew to India, my bag and slides were left in Germany, and recovery took almost two weeks.

In addition to my lectures, I spent considerable time rebuilding and reactivating a large plasma science laboratory. The laboratory was very well equipped, but had not been used for some years. Rehabilitation was complicated by a problem with electrical power. There were several power interruptions per day, of approximately one hour each. A second major problem in working at Ranchi was that telephone, telegraph, and FAX communication with the rest of the world was poor and intermittent.

Apparently, my work was appreciated, so my mission at the Birla Institute of Technology was broadened. I was given a tour of the Indian Government's Steel Research Center in Ranchi, as well as

of the Heavy Equipment Corporation, a government corporation that fabricates things such as enormous mining power shovels (electrically driven). The object was to obtain government research support for plasma engineering, including ion-implantation, surface hardening of steel and development of plasma cutting torches.

I also was approached for starting a company for the manufacture of plasma engineering teaching kits. This project would be started in the innovation center, and the products would be sold world-wide.

The director of the institute, Professor H. C. Pande, has recently notified me that the Birla management has decided to support the development of a plasma laboratory by an internal grant of 10^6 Rupees, which goes a long way in India, but is only $40,000 USA.

After completing my lectures and laboratory renovation, Professor Pande rewarded me with a tour of India. I was flown to Dehli, then Udapur. Next I took an enormous tour in a rented taxi across the Rajahastan desert to visit the amazing Jain Temples on Mount Abu. Next, I flew to Jaipur, to see the enormous research and innovation center being developed by Birla at this site. I also visited an Indian village that also had its own successful innovation center. Finally, there was another enormous taxi trip from Jaipur to Dehli to catch my plane home.

My general impressions are that India is doing well, and is moving away from the "Soviet-Style" directed economy to a more Western form of industrialization. I greatly enjoyed my stay, and want to work with these people. They must have liked me - my visa is for 5 years and unlimited number of entries.

Atmospheric Plasmas

Concerning our atmospheric pressure ion plasmas, we have had an extremely successful start. The discharge currents run from 5 to 100 microamperes. Although the current is low, the slow ion migration results in remarkable ion densities - over 10^{10} ions/cm^3. The Debye radius at this high density and low temperature corresponds to a very small 5 microns! This is still about 10x larger than the ion-gas atom mean free path.

The lack of visible light from these ion plasmas is probably the reason that they have been neglected in the past. We would expect some kind of recombination radiation, but it may be faint, in the ultraviolet, or in the infrared. A search for such radiation will be made shortly.