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**HANDY GUIDE TO THE PRESHOT ANALYSIS
FOR INTERFEROMETRIC MEASUREMENTS**

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HANDY GUIDE TO THE PRESHOT ANALYSIS FOR INTERFEROMETRIC MEASUREMENTS

ABSTRACT

Two methods of preshot analysis for measurements which require a laser Doppler interferometer are described. Both methods have the same goal. Prior to the experiment, the velocity history to be measured is calculated using the best available data on the material. Then the calculated velocities are translated into an interferometric fringe pattern. Such an approach to interferometric measurements is very useful when one attempts to measure complex velocity profiles where the frequency of the signals to be recorded varies greatly during the measurement. In such an experiment, the frequency can often exceed the bandwidth of the photomultiplier. By making the preshot analysis of the interferometric data, one can avoid the risk of losing important data by properly adjusting the interferometer before the experiment. An example is given to demonstrate the usefulness of both methods.

INTRODUCTION

This note describes convenient methods of preparatory analysis for the interferometric data when the measurement requires a laser Doppler interferometer. A serious limitation placed on the laser interferometer is the bandwidth or the response characteristics of the photomultiplier which is an essential component of the interferometer. When the frequency of the signals to be measured exceeds the bandwidth of the photomultiplier the resultant data are incomplete, in which case the experimenter fills in the missing data with his "intelligent guess." To compound the difficulty, the frequency of the signal is not uniform during the measurement. Usually one observes a burst of signals upon the arrival of a shock wave followed by no signal during a period of constant velocity. At a later time, a release wave again brings low-frequency signals.

The signal frequency can be adjusted before the measurement by properly setting the adjustable optical delay on the interferometer if we have some prior knowledge of the velocity history to be measured. The optical delay is set so that the most important segment of the data is completely recorded, thus making a compromise on the remaining portion of the data. We have developed convenient methods to fulfill this objective.

The first method described in this report is a two-step process. First, the velocities of the surface to be measured are calculated for a given experiment with a B-Division code, KO, using the best available equation-of-state. The calculated

velocities are written out on a tape. The second step is the conversion of the velocities into the interferometric data; i.e., a fringe pattern. This will provide the crucial information on the frequencies of the signals that the experimenter can expect during the measurement.

This kind of approach to interferometric measurements is particularly important when we attempt to measure complex velocity profiles such as we observe in hydro-experiments. For this purpose, we developed the second method. Taking the old data on the velocity history for a similar hydro-experiment; e.g., a streak record, we crudely digitize the velocity-versus-time plot. Then the velocity history is translated into the interferometric data.

These methods were tested and proved to work very well. The computer programs are attached at the end of the report for the convenience of the users.

FROM KO CALCULATION TO FRINGE PATTERN

Step 1

The first step is a KO calculation of the velocities. This requires a proper problem deck. The KO-problem deck is preceded by the following control cards:

```
*ID
* XEQ KOELAS
* ADT Tape# CIFILE
*V Tape #
*DATA
```

The standard KO input is used to set up all the problem except the J-number of the surface where the velocities are being calculated. The J-number is given by an input variable, MKU, according to the following rules:

1. MKU = Positive Integer

MKU is the J-number of the outermost zone; i.e., the free-surface of the target where the velocities are being calculated. Note that

$$\text{MKU} = \text{Total Number of Zone} + 1$$

2. MKU = Negative Integer

High-pressure measurements often require an optical window in contact with the free surface where the velocities are interrogated. In this case, MKU is the region number of the optical window given by a negative integer. The velocities are calculated at the inner boundary of the region.

The calculated velocities are written onto a tape as file CIFILE.

Step 2

The second step is the translation of the velocities into a fringe pattern. The operation is performed by an interactive program CALCI. The program CALCI is stored in the photostore in the directory, .FCALCI. CALCI performs the conversion of the velocities into a fringe pattern by the following equation¹:

For $0 \leq t \leq \tau$

$$I = A \cos^2 \left(\phi_0 + \frac{2\pi tU}{\lambda} \right)$$

for $\tau < t$

$$I = A \cos^2 \left(\phi_0 + \frac{2\pi \tau U}{\lambda} \right)$$

where τ is the light transit time along the optical delay.

It is probably most instructive if the entire operation on a teletype is explicitly described showing the input messages by arrow signs. The operation is as follows:

1. To read the calculated velocities

→ Ask operator for Tape #

[OK]

→ RDFS Tapes # CIFILE / T V

ALL DONE

2. To read out CALCI from the photostore

→ ELF / T V

→ .RDS .FCALCI:CALCI

.RDS

→ END

ALL DONE

3. To convert the velocities into a fringe pattern:

→ CALCI / T V

BOXAAA ID

→ BOXC61 M. KAMEGAI

COMPILED - 02/12S 14.34.54 RUN - 15:01:26S 02/12/74

TYPE INPUT - N59 XN.XM YN YM AI TOI VI X1I GI YCI VMIN (see footnote 1)

?

→ 0 0. 1. -3. 2. -1. 0. 3.E4 2.05 156. .5268 2.E-4

0 0. 1. -3. 2.

-1. 0. 3.E4 2.05 156. .5268 2.E-4

TYPE YES OR NO (see footnote 2)

?

1. M. Kamegai, Analysis of a Laser Doppler Interferometer, UCRL-75452-ppt, February 9, 1974 (submitted to Applied Optics Letters).

→ YES
 CIFILE GENERATED - 23:06:21 T02/11/74
 D3819B
 TIME 1.4153398 TAO = 5.13167E-03 (see footnote 3)
 SCALE CHANGE (see footnote 4)
 ?
 → YES
 XN XM YN YM
 ?
 → 0. .6 -3. 2.
 0. .6 -3. 2.
 OK ?
 → OK
 SCALE CHANGE
 ?
 → YES
 XN XM YN YM
 ?
 → .3 .6 -3. 2.
 3. .6 -3. 2.
 OK ?
 → OK
 SCALE CHANGE
 ?
 → NO
 ALL DONE

FOOTNOTES:

1. Definition

- N59 = 1 Type all the velocities and times on the teletype.
 = 0 Do not type the velocities and times on the teletype.
 XN = Minimum scale for time.
 XM = Maximum scale for time.
 YN = Minimum scale for amplitude
 YM = Maximum scale for amplitude
 AI = Fringe amplitude
 TOI = Initial phase ϕ (in radian)
 VI = Velocity of light (in cm/ μ s)
 X1I = Reference path (in cm)
 GI = Delay path (in cm)
 YCI = $1/\lambda C$
 VMIN = Cut-off velocity
2. YES means that the teletype agrees with the input quantities.
 NO means that the teletype does not agree with the input.
3. TIME = Time when the surface began to move.
 TAO = Light transit time along the optical delay.
4. SCALE CHANGE allows the enlargement of a segment of the fringe pattern.
 Both amplitude and time scales can be changed.

The results are written into a DX-file which can be viewed on a screen and sent out to either RJET or CRT by the following method:

1. To send to RJET as it is displayed on a screen:

```
→ EXE HEED DDTVRJ DR. / T V
  ALL DONE
→ DDTVRJ Screen #      / T V
  TYPE DD80 FILENAME
→ .DX-file
→ .S 5 (skip 5 pages)
→ .RJ
  TYPE RJET# BOX AND ID
→ # BOX C61 M. KAMEGAI
→ .END
  ALL DONE
```

2. To send to CRT:

```
→ GIVE DX-file 999999 / T V
  OK
→ END
  ALL DONE
```

The source program for CALCI is called CICAL, which is attached at the end of the report.

Figure 1 shows an example. The free-surface velocities were calculated for an aluminum impact experiment at 13 kb prior to the measurement. The velocity history is displayed, together with the predicted fringe pattern and the actual interferometric data. This example clearly demonstrates the usefulness of the method.

FROM HYDRO-VELOCITY HISTORY TO FRINGE PATTERN

This method is a crude preshot analysis of the interferometric data for hydro-experiments. Taking the old data on a similar hydro-experiment, we digitize the velocity history. In analyzing a very complex velocity profile which is characteristic to hydro-experiments, accuracy required on timing greatly varies over the velocity plot. Thus, in digitizing the velocity history, varied interval times are taken in different regions of the plot.

Furthermore, the pressures achieved in hydro-implosions are quite extraordinary. This imposes very severe requirements on instrumentation. The most suitable

Fig. 1. An example of the calculated fringe pattern.

interferometer for this type of measurement is a diffuse Doppler interferometer. Since the diffuse interferometer characteristically operates on a complex optical delay path, all the components of the optical delay must be considered in calculating the light transit time through the delay path.

The deck we prepare after the velocities have been digitized is called INPUT. INPUT-deck consists of an ID-card followed by all the input quantities. END-card marks the end of the deck. Each card may contain any number of input quantities or input variables. Only one space is required between any two adjacent numbers or variables. INPUT-deck is arranged in the following order*:

```
IDU458850 INPUT
V1 = 2. 2.3 2.71 etc.
4.21 4.4 4.62 etc.
V2 = 6.2 6.7 6.91 V3 = 7.21 7.3 etc.
DTL = .01 DT2 = .5 DT = .01 etc.
VC = .1 A = -1. PHI0 = 0. etc.
. . .
. . .
. . .
END
```

The code which translates the digitized velocities into a fringe pattern is called FRINGE. The fringe pattern is calculated by¹

$$I = A \cos^2 \left(\phi_0 + \frac{2\pi \tau U}{\lambda} \right)$$

where τ is the light transit time through the delay. FRINGE is run by the ORDER system. It reads the file INPUT for data.

The operational procedure is as follows:

Read FRINGE in a 7600

Read INPUT in a 7600

Operate by a standard method,

ORDER FRINGE / T V.

* Definition

V1, V2, V3, V4, V5 = Velocities in arbitrary unit in regions 1, 2, 3, 4, and 5.

DT1, DT2, DT3, DT4, DT5 = Time steps taken in regions 1, 2, 3, 4, and 5.

A = Fringe amplitude (usually -1.)

PHI0 = Initial phase (radian)

XR = Total reference path (cm)

XE = Total path through etalon (cm)

XA = Total path through air space (cm)

XQW = Total path through $\lambda/4$ -plate (cm)

XBS = Total path through beamsplitter (cm)

RIE = Etalong refractive index

RIQ = $\lambda/4$ -plate refractive index

RIB = Beamsplitter refractive index

WLAM = Wavelength (cm)

VC = Factor to convert the velocities into cm/ μ s.

The result is written into a DX-file which can be viewed on a screen and sent out to either RJET or CRT. The program FRINGE is attached at the end of the report.

SUMMARY

The methods of the preshot analysis for interferometric measurements can be outlined as follows:

1. From KO-calculation to Fringe Pattern

- Step 1

- Prepare a KO-problem deck for the experiment, and calculate the velocities of the surface to be interrogated. The deck must include the special control cards (star cards) and a special input (MKU). The calculated velocities are written onto a tape as file CIFILE.

- Step 2

- Read out CALCI from the appropriate storage. Read CIFILE from the tape. Perform the conversion of the velocities into a fringe pattern by a standard method,

- CALCI / T V.

2. From Hydro-velocity to Fringe Pattern

- Crudely digitize the velocity history of a similar hydro-experiment. Prepare INPUT-deck which comprises the digitized velocities and all the input quantities. Read in INPUT and a program FRINGE separately. Perform the conversion of the velocities to a fringe pattern by the ORDER system; i.e.,

- ORDER FRINGE / T V.

This report is merely intended to be a handy guide to the preshot analysis of interferometric measurements. However, we clearly demonstrated the usefulness of the methods described in this report. Perhaps the individual experimenters should further explore such an approach to the experiment.

ACKNOWLEDGMENT

S. J. French, Jr. wrote the computer programs.

```

1 *ID 188BGH FRINGE KAMEGAI FRINGE BOX061
2 * XEQ
3 * FORTRAN
4 PROGRAM FRINGE(INPUT,HSP)
5 DIMENSION FI(1000),TI(1000),V1(1000),V2(1000),V3(1000),V4(1000),
6 V5(1000)
7 NAMELIST/DOG/V1,V2,V3,V4,V5,A,PHI0,XR,XE,XA,XQW,XBS,WLAM,
8 IRIE,RIG,RIB,DT1,DT2,DT3,DT4,DT5,VC
9 COMMON /DOFR80/ MFICHE
10 MFICHE = 1
11 WRITE(3,FOR1)
12 FOR1 FORMAT(" FRINGE INPUT"/)
13 INPUT DATA DOG,2,3
14 XDEL = XE*RIE+XQW*RIG+XBS*RIB+XA-XR
15 ARGU = 2.*3.1416*XDEL/(3.E4*WLAM)
16 DO 10 K=1,1000
17 IF(V1(K).EQ.0.)11.
18 V1(K) = VC*V1(K)
19 FI(K) = A*(COSF(PHI0+ARGU*V1(K)))*2
20 T=T+DT1
21 TI(K)=T
22 KMAX1=K
23 CONTINUE
24 DO 12 K=1,1000
25 IF(V2(K).EQ.0.)13.
26 KA=K+KMAX1
27 V2(K) = VC*V2(K)
28 FI(KA) = A*(COSF(PHI0+ARGU*V2(K)))*2
29 T=T+DT2
30 TI(KA)=T
31 KMAX2=K
32 CONTINUE
33 DO 14 K=1,1000
34 IF(V3(K).EQ.0.)15.
35 KB=K+KMAX1+KMAX2
36 V3(K) = VC*V3(K)
37 FI(KB) = A*(COSF(PHI0+ARGU*V3(K)))*2
38 T=T+DT3
39 TI(KB)=T
40 KMAX3=K
41 CONTINUE
42 DO 16 K=1,1000
43 IF(V4(K).EQ.0.)17.
44 KC=K+KMAX1+KMAX2+KMAX3
45 V4(K) = VC*V4(K)
46 FI(KC) = A*(COSF(PHI0+ARGU*V4(K)))*2
47 T=T+DT4
48 TI(KC)=T
49 KMAX4=K
50 CONTINUE
51 DO 18 K=1,1000
52 IF(V5(K).EQ.0.)19.
53 KD=K+KMAX1+KMAX2+KMAX3+KMAX4
54 V5(K) = VC*V5(K)
55 FI(KD) = A*(COSF(PHI0+ARGU*V5(K)))*2
56 T=T+DT5
57 TI(KD)=T
58 KMAX5=K
59 CONTINUE
60 KMAX=KMAX1+KMAX2+KMAX3+KMAX4+KMAX5

61 CALL CRTID(8H FRINGES,1)
62 AA = 2.*A
63 CALL KEEP80(1)
64 CALL MAPG(0.,TI(KMAX),AA,1.)
65 CALL SETCH(20.,2.,1.0,3.0,0)
66 CALL CRTBCD(4HTIME,4)
67 CALL SETCH(2.,20.,1.0,3.1,0)
68 CALL CRTBCD(9HINTENSITY,9)
69 CALL SETCRT(0.0,1.17778)
70 CALL SETPCH(1,1,1.0)
71 CALL TRACE(TI,FI,KMAX)
72 CALL EMPTY(3)
73 CALL EXIT
74 END.

```

```

1 *ID 186BCQ          CICAL          FRENCH          BOXC60
2 * RESERVE 5
3 * CONTROLLEE 0 CALCI
4 * LIST0             MAIN
5 * FORTRAN           MAIN
6   PROGRAM LIST ( T63 = 15, TAPE63 = T63, PRINT, INPUT=T63)
7   LCM A
8   COMMON /A/ A1, T01, VI, X11, GI, YCI, DTU(40000), T16(1024), NINPUT(12),
9   1   CI(20000), NUM, NOYES, DPLOT(2), EPLOT(5), NBOXID(3)
10  DIMENSION NTIDT(2)
11  COMMON/GOBCOM/ IRA((0,2))
12  DO NBXS J = 1,3
13  NBXS NBOXID(J) = 0
14  CALL GOB ( 20010, NERR, 3000, NBOXID )
15  IF ( NBOXID .EQ. 0 ) ,NBX
16  WOT 55, NBX1
17  NBX1 FORMAT ( 9HBOXAAA ID, / )
18  CALL GOB ( 20000, NERR, 3000, NBOXID )
19  NBX IRA(35) = NBOXID(1) ,SHL, 24
20  IRA(36) = NBOXID(2)
21  IRA(37) = NBOXID(3)
22  CALL CLOCK ( NTIDT(1), NTIDT(2) )
23  WOT 55, F11, IRA(30), IRA(31), NTIDT
24  PRINT F11, IRA(30), IRA(31), NTIDT
25  F11 FORMAT(//, 12H COMPILED - , 2A10, 5X, SHRUN - , 2A10, // )
26  ABSOLUTE 160(0)
27  DDTCI = 10NDXXXXXXC10
28  CALL ASSIGN ( 17, 0, SRCIFILE, 0, T16, 1024 )
29  CALL CONTROL ( 60, E1 )
30  READ TAPE 17, ( DTU(J), J = 1, 40000 )
31  E1 CALL KEEP60 ( DDTCI )
32  ; WOT 55, F1
33  F1 FORMAT(54HTYPE INPUT - N59 XN XM YN YM A1 T01 VI X11 GI YCI
34  1, //, 1H?, // )
35  NINPUT(1) = .LOC. NUM
36  CALL GOB( 20100, NERR, 14000, NINPUT )
37  IF ( NUM .EQ. 12 ) 5,
38  WOT 55, F4
39  F4 FORMAT ( 43HYOU DID NOT INPUT 12 VARIABLES AS REQUIRED., // )
40  GO TO 1,
41  5 WOT 55, F6, NINPUT
42  F6 FORMAT ( //, 2X, R1, 4R0, //, 3X, 7R0, //, 14HTYPE YES OR NO, //, 1H?, // )
43  CALL GOB( 20000, NERR, 1000, NOYES )
44  IF ( NOYES .EQ. 3RYES ) ,1
45  CALL REWIND (63)
46  WRITE (63, F2) NINPUT
47  READ (63, F3) N59, XN, XM, YN, YM, A1, T01, VI, X11, GI, YCI, VMIN
48  F2 FORMAT ( 12R10 )
49  F3 FORMAT ( 110, 11F10, 1 )
50  TAO = ( GI - X11 ) / VI
51  WOT 55, F5, (DTU(J), J=1,2), (DTU(JJ), JJ=4,9), TAO
52  PRINT F5, (DTU(J), J=1,2), (DTU(JJ), JJ=4,9), TAO
53  F5 FORMAT(//, 20HCIFILE GENERATED - , 2A10, //, 5A10,
54  1 //, 7HTIME - , F12.7, 3H TAO - , E15.5, // )
55  DPLOT(1) = DTU(1)
56  DPLOT(2) = DTU(2)
57  DO EP1 J = 1,5
58  EP1 EPLOT(J) = DTU(J+3)
59  DO A5 J = 10, 40000
60  A5 DTU(J+9) = DTU(J)
61  IF ( N59 .EQ. 0 ) 7,
62  WOT 55, F9
63  7 PRINT F9
64  F9 FORMAT( 10X, 6HDTU(J), 6X, 8HDTU(J+1), 6X, 5HC1(J), 7X, 7HC1(J+1), // )
65  DO 500 J = 1, 40000, 2
66  IF ( DTU(J) .EQ. 5555, ) 600,
67  IF (DTU(J+1) .LE. VMIN), X1
68  CI(J) = CI(J+1) - 0,
69  GO TO 22
70  X1 CI(J) = TC = TC + DTU(J)
71  IF ( CI(J) .LE. TAO ) ,15
72  CI(J+1) = A1 * ( COSF( T01 + 6.2832 * CI(J) * VI * YCI *
73  1 DTU(J+1) ) ) ** 2
74  GO TO 22
75  15 CI(J+1) = A1 * ( COSF( T01 + 6.2832 * YCI * DTU(J+1) *
76  1 ( GI - X11 ) ) ) ** 2
77  22 IF ( N59 .EQ. 0 ) 23,

```

```

78      WOT 59.F6.DTU(J),DTU(J+1),CI(J),CI(J+1)
79      23 PRINT F6,DTU(J),DTU(J+1),CI(J),CI(J+1)
80      F6 FORMAT ( 5X, 4E13.4 )
81      500 CONTINUE
82      600 NC1 = J - 1
83      NC12 = NC1 / 2
84      IF ( N59.EQ. 0 ) A600.
85      WOT 59.F600.NC1,NC12
86      F600 FORMAT ( //, 6HNC1 = , I10, 3X, 7HNC12 = , I10 )
87      A600 CALL CRTID ( 2HBH,1,1 )
88      B600 CALL FRAME ( 2 )
89      CALL SETCRT ( 1.,1.,1.0 )
90      CALL MAPX ( 9,XN,XM,YN,YM )
91      CALL SETCH( 1., 20., 1.0,2.1 )
92      WOT 100.F7A.DPLOT
93      F7A FORMAT(22HUCIFILE GENERATED - , 2A10 )
94      CALL SETCH ( 5., 1., 1.0,2.0 )
95      WOT 100.F7.(F7PLOT(J),J=1,5)
96      F7 FORMAT ( 5A10 )
97      CALL TRACE ( CI(1), CI(2), NC12, 2, 2 )
98      G2 WOT 59.F12
99      F12 FORMAT( 13HSCALE CHANGE,/,1H7,/)
100     CALL GOB( 20000,NEER,1000,NINPUT )
101     IF ( NINPUT.EQ. 3RYES ) G1.
102     IF ( NINPUT.EQ. 2RNO ) G5.
103     IF ( NINPUT.EQ. 3REND ) G5,G2
104     G1 WOT 59.FG1
105     FG1 FORMAT ( 10H XN XM YN YM,/,1H7,/)
106     NINPUT(1) = .LOC. NUM
107     CALL GOB ( 20000,NEER,4000,NINPUT )
108     IF ( NUM.EQ. 4 ) G3.
109     WOT 59.FG2
110     FG2 FORMAT( 42HYOU DID NOT TYPE 4 VARIABLES AS REQUIRED,/)
111     GO TO G1
112     G3 WOT 59.FG3.(NINPUT(J),J=1,4)
113     FG3 FORMAT( //, 2X,4R10,/,4HOK 7,/)
114     CALL GOB ( 20000,NEER,1000,NOYES )
115     IF ( NOYES.EQ. 2ROK ) G1
116     REMIND (63)
117     WRITE ( 63,DG1 ) (NINPUT(J),J=1,4)
118     READ ( 63,DG2)XN,XM,YN,YM
119     DG1 FORMAT( 4R10 )
120     DG2 FORMAT ( 4F10,1 )

121     GO TO 0600
122     G5 CALL PLOTE
123     CALL EXIT
124     RETURN
125     END

61     CALL CRTID(0H FRINGES,1)
62     AA = 2.*A
63     CALL KEEP00(1)
64     CALL MAPG(0.,TI(KMAX),AA,1.)
65     CALL SETCH(20.,2.,1.0,3.0,0)
66     CALL CRTBCD(4HTIME,4)
67     CALL SETCH(2.,20.,1.0,3.1,0)
68     CALL CRTBCD(9HINTENSITY,9)
69     CALL SETCRT(0.0,1.17778)
70     CALL SETPCH(1,1,1,0)
71     CALL TRACE(TI,F1,KMAX)
72     CALL EMPTY(3)
73     CALL EXIT
74     END

```

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