



1  
00:00:00,790 --> 00:00:07,320

[Music]

2  
00:00:13,240 --> 00:00:09,060

[Applause]

3  
00:00:16,000 --> 00:00:13,250  
so yeah this is Chris session so I'm

4  
00:00:18,130 --> 00:00:16,010  
Chris Onan Smith I'm at JPL we're doing

5  
00:00:19,690 --> 00:00:18,140  
this in collaboration with Jana Dell at

6  
00:00:22,510 --> 00:00:19,700  
Portland State she's a lead there and

7  
00:00:23,589 --> 00:00:22,520  
the Gareeb lab at Caltech I'm actually

8  
00:00:26,890 --> 00:00:23,599  
gonna talk about a little more than

9  
00:00:28,300 --> 00:00:26,900  
holographic microscopy here's a bunch of

10  
00:00:30,279 --> 00:00:28,310  
people over the years who worked with us

11  
00:00:31,540 --> 00:00:30,289  
and some of the people are new who

12  
00:00:33,369 --> 00:00:31,550  
didn't contribute necessarily to this

13  
00:00:35,140 --> 00:00:33,379

but we've got a lot going on and so

14

00:00:38,619 --> 00:00:35,150

there's a lot there will be reporter in

15

00:00:40,540 --> 00:00:38,629

other areas so background I think Alison

16

00:00:42,540 --> 00:00:40,550

and Richard covered pretty well why we

17

00:00:45,910 --> 00:00:42,550

want to do imaging one thing I want to

18

00:00:48,160 --> 00:00:45,920

highlight here is a quote from the 65

19

00:00:50,080 --> 00:00:48,170

paper by Lovelock where everybody likes

20

00:00:52,389 --> 00:00:50,090

to quote that for talking about the

21

00:00:54,610 --> 00:00:52,399

looking for chemical structure but he

22

00:00:56,350 --> 00:00:54,620

also pointed out imaging is a really

23

00:00:59,350 --> 00:00:56,360

important way for us to detect extant

24

00:01:01,660 --> 00:00:59,360

life somewhere and the problem in 1965

25

00:01:03,700 --> 00:01:01,670

was that cameras were awful the laser

26  
00:01:04,600 --> 00:01:03,710  
was a couple years old the CCD hadn't

27  
00:01:06,820 --> 00:01:04,610  
been invented yet

28  
00:01:07,960 --> 00:01:06,830  
laser diode was a couple years old we

29  
00:01:09,940 --> 00:01:07,970  
have all those things now and they're

30  
00:01:13,330 --> 00:01:09,950  
very cheap and we can take advantage of

31  
00:01:18,100 --> 00:01:13,340  
those um so what we want to deal with

32  
00:01:19,120 --> 00:01:18,110  
imaging is down here is there's a lot of

33  
00:01:21,580 --> 00:01:19,130  
interesting stuff that you can see with

34  
00:01:22,840 --> 00:01:21,590  
electron microscopy AFM but it's not

35  
00:01:25,030 --> 00:01:22,850  
that great for search because you've got

36  
00:01:27,039 --> 00:01:25,040  
this tiny tiny volume of you so with

37  
00:01:29,530 --> 00:01:27,049  
optical microscopy you can look in the

38  
00:01:31,120 --> 00:01:29,540

100 nanometer route to say a micron or

39

00:01:33,910 --> 00:01:31,130

even tens of microns range depending on

40

00:01:35,440 --> 00:01:33,920

your instrument and typical microscopes

41

00:01:37,960 --> 00:01:35,450

that you see in the lab if you're just a

42

00:01:39,310 --> 00:01:37,970

microbiologist have a volume of you

43

00:01:40,660 --> 00:01:39,320

that's really tiny so if you're looking

44

00:01:42,219 --> 00:01:40,670

for something that's a hundred per

45

00:01:44,289 --> 00:01:42,229

milliliter you have to look at a lot of

46

00:01:47,170 --> 00:01:44,299

slides before you get anywhere we've

47

00:01:48,640 --> 00:01:47,180

built a microscope called Ishmael icy

48

00:01:51,760 --> 00:01:48,650

surface holographic microscope for

49

00:01:54,010 --> 00:01:51,770

analysis of your open life that has a

50

00:01:57,340 --> 00:01:54,020

very huge volume of us a millimeter

51  
00:01:59,380 --> 00:01:57,350  
thick at full sub micron resolution and

52  
00:02:00,819 --> 00:01:59,390  
that's our whole graphic microscope we

53  
00:02:03,969 --> 00:02:00,829  
also have fluorescence that we've added

54  
00:02:06,130 --> 00:02:03,979  
to it that I'm going to talk about so

55  
00:02:08,080 --> 00:02:06,140  
here's the summary of the whole thing up

56  
00:02:09,850 --> 00:02:08,090  
front we've combined two microscopes

57  
00:02:11,800 --> 00:02:09,860  
we've got a holographic microscope here

58  
00:02:13,870 --> 00:02:11,810  
it does high-resolution imaging at some

59  
00:02:15,610 --> 00:02:13,880  
micron we're looking at a volume a

60  
00:02:17,949 --> 00:02:15,620  
millimeter thick by half millimeter by

61  
00:02:20,020 --> 00:02:17,959  
half a millimeter and one of the

62  
00:02:21,369 --> 00:02:20,030  
restrictions of holography is you can't

63  
00:02:23,290 --> 00:02:21,379

really do fluorescence with it because

64

00:02:25,180 --> 00:02:23,300

we depend on coherent light to do that

65

00:02:27,309 --> 00:02:25,190

so we wanted to do fluorescence we

66

00:02:30,130 --> 00:02:27,319

wanted to be able to do stains and do

67

00:02:31,570 --> 00:02:30,140

chemical it on labeling of cells so what

68

00:02:33,670 --> 00:02:31,580

we did is we put on a beam splitter and

69

00:02:35,350 --> 00:02:33,680

we're using the same objectives in the

70

00:02:36,940 --> 00:02:35,360

same field of view and we've added

71

00:02:40,509 --> 00:02:36,950

another microscope it's a light field

72

00:02:42,040 --> 00:02:40,519

microscope that looks at exactly the

73

00:02:43,300 --> 00:02:42,050

same thing at the same time but we can

74

00:02:44,979 --> 00:02:43,310

look at all the fluorescence or we can

75

00:02:46,750 --> 00:02:44,989

look at things for just color if we want

76

00:02:48,610 --> 00:02:46,760

to look for pigments if we have a color

77

00:02:50,860 --> 00:02:48,620

camera back here and both of these are

78

00:02:52,600 --> 00:02:50,870

compressive techniques we're a single

79

00:02:54,460 --> 00:02:52,610

hologram or a single light field image

80

00:02:56,830 --> 00:02:54,470

captures everything that's in that

81

00:02:59,410 --> 00:02:56,840

volume at the full resolution of the

82

00:03:02,170 --> 00:02:59,420

system we've sacrifice resolution in the

83

00:03:03,910 --> 00:03:02,180

light field because of features of light

84

00:03:08,199 --> 00:03:03,920

field microscopy but we've got that all

85

00:03:09,640 --> 00:03:08,209

all that resolution here and then we

86

00:03:12,670 --> 00:03:09,650

from the single image we get chemical

87

00:03:16,270 --> 00:03:12,680

composition or we can get structure and

88

00:03:18,220 --> 00:03:16,280

optical properties from time series we

89

00:03:20,649 --> 00:03:18,230

can get cellular chemistry as things

90

00:03:22,570 --> 00:03:20,659

change you could do flim or we can do

91

00:03:24,930 --> 00:03:22,580

mass density and activity from time

92

00:03:27,720 --> 00:03:24,940

series we can extract all those things

93

00:03:30,070 --> 00:03:27,730

so how the holographic microscope works

94

00:03:32,199 --> 00:03:30,080

it looks a lot like a regular microscope

95

00:03:35,380 --> 00:03:32,209

so we've got a light source we've got a

96

00:03:37,660 --> 00:03:35,390

lens here that's an objective lens we've

97

00:03:39,910 --> 00:03:37,670

got our sample and then we've got a

98

00:03:41,559 --> 00:03:39,920

detector back here and we really use

99

00:03:43,570 --> 00:03:41,569

very simple objectives back here because

100

00:03:44,740 --> 00:03:43,580

we are using monochromatic light we

101  
00:03:46,390 --> 00:03:44,750  
don't have to have all the chromatic

102  
00:03:48,550 --> 00:03:46,400  
aberration correction then we have a

103  
00:03:50,170 --> 00:03:48,560  
second beam that we use as a clock

104  
00:03:52,059 --> 00:03:50,180  
basically we just put water in there and

105  
00:03:53,800 --> 00:03:52,069  
we get an interference pattern back here

106  
00:03:55,780 --> 00:03:53,810  
so our second beam hasn't gone through

107  
00:03:57,220 --> 00:03:55,790  
anything but water same path length so

108  
00:03:59,410 --> 00:03:57,230  
we know exactly how long it should have

109  
00:04:00,699 --> 00:03:59,420  
taken to go through here the sample that

110  
00:04:03,009 --> 00:04:00,709  
we're looking at whether it's got bugs

111  
00:04:04,449 --> 00:04:03,019  
or rocks or something in it has been

112  
00:04:06,070 --> 00:04:04,459  
perturbed by the sample and we can back

113  
00:04:07,630 --> 00:04:06,080

propagate to figure out what was in the

114

00:04:09,160 --> 00:04:07,640  
sample so we take some freight

115

00:04:10,839 --> 00:04:09,170  
transforms and multiply by a phase

116

00:04:12,070 --> 00:04:10,849  
vector and we can reconstruct an

117

00:04:14,170 --> 00:04:12,080  
amplitude image that's just like a

118

00:04:16,360 --> 00:04:14,180  
regular picture or we can reconstruct a

119

00:04:18,759 --> 00:04:16,370  
phase image that we don't have a sort of

120

00:04:20,710 --> 00:04:18,769  
classical analog for but what it is is

121

00:04:22,450 --> 00:04:20,720  
essentially the thickness of the sample

122

00:04:24,320 --> 00:04:22,460  
times of the index refraction difference

123

00:04:26,270 --> 00:04:24,330  
between the sample on the medium

124

00:04:28,760 --> 00:04:26,280  
and so we can combine these it's

125

00:04:30,020 --> 00:04:28,770  
basically all of the electric field is

126

00:04:31,460 --> 00:04:30,030

captured in here we can combine these

127

00:04:33,770 --> 00:04:31,470

into any form of image we want without

128

00:04:36,559 --> 00:04:33,780

having to put any stings in the caches

129

00:04:37,879 --> 00:04:36,569

we don't get the chemistry of things we

130

00:04:41,779 --> 00:04:37,889

can do with that we can do structure

131

00:04:43,999 --> 00:04:41,789

review but from a pond we get diatoms we

132

00:04:45,080 --> 00:04:44,009

can do intensity and phase images of

133

00:04:47,629 --> 00:04:45,090

various things we can look at things

134

00:04:51,679 --> 00:04:47,639

over time so this is a 1 micron particle

135

00:04:53,480 --> 00:04:51,689

being tracked for several seconds now

136

00:04:56,089 --> 00:04:53,490

we've got a huge dynamic range so this

137

00:04:58,129 --> 00:04:56,099

is a he just ran away he's coming back

138

00:05:00,469 --> 00:04:58,139

here a huge diatoms about 40 microns

139

00:05:02,869 --> 00:05:00,479

long and then over here is like a little

140

00:05:04,879 --> 00:05:02,879

1 micron thing swimming around in there

141

00:05:06,740 --> 00:05:04,889

so all of this is just a single

142

00:05:07,999 --> 00:05:06,750

reconstruction plane all of the other

143

00:05:10,040 --> 00:05:08,009

stuff that's moving in there we can

144

00:05:12,619 --> 00:05:10,050

reconstruct from the same Holograms or

145

00:05:15,409 --> 00:05:12,629

the hologram time series and get all of

146

00:05:18,200 --> 00:05:15,419

those things that are in that volume in

147

00:05:21,559 --> 00:05:18,210

that time and track them so here's an

148

00:05:23,659 --> 00:05:21,569

example of Brownian motion we basically

149

00:05:25,249 --> 00:05:23,669

have buoyant cells that are non motile

150

00:05:28,879 --> 00:05:25,259

they just kind of bounce around they

151  
00:05:30,379 --> 00:05:28,889  
don't do much we've got one micron

152  
00:05:33,409 --> 00:05:30,389  
alumina B it's they just sink like rocks

153  
00:05:35,990 --> 00:05:33,419  
which you kind of expect and then we've

154  
00:05:37,999 --> 00:05:36,000  
got actual swimming bacteria that are

155  
00:05:39,769 --> 00:05:38,009  
the same sizes of these and they go all

156  
00:05:41,629 --> 00:05:39,779  
over the place and you can see a little

157  
00:05:45,079 --> 00:05:41,639  
corkscrew here that I pulled one out um

158  
00:05:46,939 --> 00:05:45,089  
but they swim like crazy now we also can

159  
00:05:48,829 --> 00:05:46,949  
get refractive index information to tell

160  
00:05:50,869 --> 00:05:48,839  
things apart so you can tell ecoli from

161  
00:05:52,579 --> 00:05:50,879  
Illumina here because the index of

162  
00:05:55,399 --> 00:05:52,589  
refraction difference it's one point

163  
00:05:58,790 --> 00:05:55,409

three versus one point eight and they're

164

00:06:01,040 --> 00:05:58,800

indicated there we've got a biofilm

165

00:06:03,469 --> 00:06:01,050

where you can barely tell anything from

166

00:06:05,450 --> 00:06:03,479

the amplitude picture but from the face

167

00:06:07,100 --> 00:06:05,460

picture you can tell that these big

168

00:06:09,409 --> 00:06:07,110

crystals that turned out they actually

169

00:06:10,579 --> 00:06:09,419

stained when they stained them as

170

00:06:12,079 --> 00:06:10,589

looking like they were alive they're

171

00:06:14,119 --> 00:06:12,089

actually sulfur by the index refraction

172

00:06:15,339 --> 00:06:14,129

and they actually spent a year trying to

173

00:06:19,249 --> 00:06:15,349

figure out whether they were alive or

174

00:06:22,519 --> 00:06:19,259

alive or not before they try to dhm an

175

00:06:24,559 --> 00:06:22,529

index method on them and even some

176  
00:06:26,360 --> 00:06:24,569  
micron things we can sort of tell what's

177  
00:06:28,369 --> 00:06:26,370  
going on now we've got alumina particles

178  
00:06:30,769 --> 00:06:28,379  
here and the air filled vesicles here

179  
00:06:32,159 --> 00:06:30,779  
and you can tell them apart they're both

180  
00:06:38,249 --> 00:06:32,169  
well below the resolution limit

181  
00:06:39,719 --> 00:06:38,259  
microscope and to segue into this for

182  
00:06:41,939 --> 00:06:39,729  
unresolved objects we can actually do

183  
00:06:44,519 --> 00:06:41,949  
modeling of the diffraction pattern I'm

184  
00:06:47,659 --> 00:06:44,529  
using discrete dipole approximation to

185  
00:06:50,279 --> 00:06:47,669  
get out the geometry say spherical or

186  
00:06:52,769 --> 00:06:50,289  
hexagonal or like a pill like a

187  
00:06:54,179 --> 00:06:52,779  
bacterium and get the index of

188  
00:06:56,219 --> 00:06:54,189

refraction on the geometry at the same

189

00:06:57,390 --> 00:06:56,229

time so we get a lot of information even

190

00:07:01,230 --> 00:06:57,400

about things that we can't image

191

00:07:03,749 --> 00:07:01,240

directly but we can tell her there am

192

00:07:06,439 --> 00:07:03,759

light field is a interesting technique

193

00:07:08,670 --> 00:07:06,449

one of the penalties is you sacrifice

194

00:07:10,350 --> 00:07:08,680

angular resolution as you get depth of

195

00:07:14,219 --> 00:07:10,360

field from it and so that's why we gave

196

00:07:16,439 --> 00:07:14,229

up resolution of to get the fluorescence

197

00:07:18,809 --> 00:07:16,449

imaging but what it does is instead of

198

00:07:20,399 --> 00:07:18,819

putting a detector rate the focus you

199

00:07:22,769 --> 00:07:20,409

put a lens letter right here and then

200

00:07:24,510 --> 00:07:22,779

you put a detector behind that and what

201  
00:07:26,369 --> 00:07:24,520  
happens is you can tell the angle at

202  
00:07:28,950 --> 00:07:26,379  
which every ray came through the system

203  
00:07:30,149 --> 00:07:28,960  
and then track backwards to figure out

204  
00:07:32,010 --> 00:07:30,159  
where the particle was so if you've got

205  
00:07:33,989 --> 00:07:32,020  
something that was in focus it shows up

206  
00:07:36,450 --> 00:07:33,999  
as a spot at the center if you get this

207  
00:07:38,010 --> 00:07:36,460  
particle back here it shows up as these

208  
00:07:39,480 --> 00:07:38,020  
little spots at that outside the little

209  
00:07:40,709 --> 00:07:39,490  
ones that are raised if it was at the

210  
00:07:43,379 --> 00:07:40,719  
same distance in front you would be in

211  
00:07:46,499 --> 00:07:43,389  
the same one so two rays but you would

212  
00:07:47,879 --> 00:07:46,509  
be on the insides because of the way the

213  
00:07:49,469 --> 00:07:47,889

Rays go through the system and so we can

214

00:07:51,089 --> 00:07:49,479

back all that out and we can figure out

215

00:07:53,309 --> 00:07:51,099

where something came from so we can

216

00:07:55,860 --> 00:07:53,319

associate the fluorescence from

217

00:07:57,510 --> 00:07:55,870

something that's reduced resolution with

218

00:07:59,249 --> 00:07:57,520

the high resolution image from the

219

00:08:02,670 --> 00:07:59,259

holographic microscope and so here's an

220

00:08:05,489 --> 00:08:02,680

example of both together here's the

221

00:08:07,079 --> 00:08:05,499

whole system laid out on bench top it's

222

00:08:09,679 --> 00:08:07,089

basically two microscope side-by-side

223

00:08:12,149 --> 00:08:09,689

connected by a couple beam splitters and

224

00:08:13,350 --> 00:08:12,159

we've actually got it mounted up on a

225

00:08:15,119 --> 00:08:13,360

vertical system so it looks like a

226

00:08:16,260 --> 00:08:15,129

microscope but it photographs better

227

00:08:20,369 --> 00:08:16,270

when it's laying down because you don't

228

00:08:23,850 --> 00:08:20,379

have all the whole lab stuff here's

229

00:08:25,079 --> 00:08:23,860

pictures from Max's talk from Tuesday if

230

00:08:27,540 --> 00:08:25,089

you have a time machine you can go see

231

00:08:28,829 --> 00:08:27,550

his talk so here's the raw detector

232

00:08:31,200 --> 00:08:28,839

output of Euglena

233

00:08:32,939 --> 00:08:31,210

if you're looking at the system with

234

00:08:35,279 --> 00:08:32,949

euglena head to focus and then the

235

00:08:36,779 --> 00:08:35,289

reconstruction it doesn't look that much

236

00:08:38,129 --> 00:08:36,789

different but when they're 100 microns

237

00:08:39,480 --> 00:08:38,139

out of focus you can barely tell that

238

00:08:40,649 --> 00:08:39,490

they're there if you do the

239

00:08:42,630 --> 00:08:40,659

reconstruction you can see them swimming

240

00:08:43,970 --> 00:08:42,640

all over here and you get the

241

00:08:46,120 --> 00:08:43,980

reconstruction there

242

00:08:49,360 --> 00:08:46,130

here's combined output of the two

243

00:08:52,590 --> 00:08:49,370

systems the green is just the background

244

00:08:55,480 --> 00:08:52,600

from the dhm and we've got resolved

245

00:08:58,150 --> 00:08:55,490

particles and we put pink blobs on top

246

00:09:00,010 --> 00:08:58,160

that came out of the white field system

247

00:09:01,840 --> 00:09:00,020

and so we can add stains just like

248

00:09:03,760 --> 00:09:01,850

Richard talked about to detect things

249

00:09:05,710 --> 00:09:03,770

like lipids or proteins or nucleic acids

250

00:09:07,450 --> 00:09:05,720

and everybody as he said has their

251

00:09:10,950 --> 00:09:07,460

favorite stains for picking their

252

00:09:14,130 --> 00:09:10,960

favorite things we've packaged up the

253

00:09:17,050 --> 00:09:14,140

THM into Europa Lander size package now

254

00:09:20,800 --> 00:09:17,060

this fits into the two you basically a

255

00:09:22,330 --> 00:09:20,810

two liter volume and so you make it I

256

00:09:23,920 --> 00:09:22,340

don't work with the white field we

257

00:09:26,530 --> 00:09:23,930

probably have to add a second tube about

258

00:09:31,380 --> 00:09:26,540

this big and a little bit of stuff off

259

00:09:33,520 --> 00:09:31,390

the side or off the angle like that and

260

00:09:38,290 --> 00:09:33,530

multi-wavelength is a feature we also

261

00:09:40,180 --> 00:09:38,300

can do one artifact of our laziness and

262

00:09:42,520 --> 00:09:40,190

how not having abuse letters in the

263

00:09:46,750 --> 00:09:42,530

whole whole graphic microscope

264

00:09:49,210 --> 00:09:46,760

so the first microscope I showed is just

265

00:09:50,890 --> 00:09:49,220

any pair of these is just like that is

266

00:09:52,270 --> 00:09:50,900

so what we do is we just put three

267

00:09:54,820 --> 00:09:52,280

different holographic microscopes at

268

00:09:57,070 --> 00:09:54,830

different angles we put a color filter

269

00:09:59,950 --> 00:09:57,080

in front of each one and we leave the

270

00:10:02,140 --> 00:09:59,960

central hole bare combined three lasers

271

00:10:05,170 --> 00:10:02,150

together and what we get is set of

272

00:10:07,330 --> 00:10:05,180

fringes that are crossed at 120 degree

273

00:10:08,980 --> 00:10:07,340

angles when we Fourier transform that

274

00:10:10,660 --> 00:10:08,990

each color shows up separately in the

275

00:10:12,810 --> 00:10:10,670

Fourier plane so we can do a

276

00:10:14,050 --> 00:10:12,820  
reconstruction of each different

277

00:10:16,270 --> 00:10:14,060  
wavelength

278

00:10:19,540 --> 00:10:16,280  
completely independently overlay them on

279

00:10:21,100 --> 00:10:19,550  
each other and then we've got nice color

280

00:10:23,290 --> 00:10:21,110  
images of Euglena using a monochromatic

281

00:10:24,670 --> 00:10:23,300  
sensor and three lasers and that gives

282

00:10:26,140 --> 00:10:24,680  
us nice redundancy - you could lose a

283

00:10:28,540 --> 00:10:26,150  
laser you don't lose that much

284

00:10:33,900 --> 00:10:28,550  
information now here's a movie at the

285

00:10:36,450 --> 00:10:33,910  
bottom I think I hit it autoplay yeah

286

00:10:38,950 --> 00:10:36,460  
yeah you can see him swimming around in

287

00:10:40,840 --> 00:10:38,960  
and you can see their little eye spot

288

00:10:43,120 --> 00:10:40,850

and here's the eye spot they've got a

289

00:10:44,320 --> 00:10:43,130

little nucleus there and a nucleolus so

290

00:10:49,150 --> 00:10:44,330

you can get a lot out of it

291

00:10:50,860 --> 00:10:49,160

um future work field implementation with

292

00:10:53,710 --> 00:10:50,870

the complex Compaq lensless version I

293

00:10:56,110 --> 00:10:53,720

didn't talk about oh and that's what

294

00:10:58,180 --> 00:10:56,120

we're doing now and sure that our sample

295

00:10:58,480 --> 00:10:58,190

delivery system nado Bernie I don't know

296

00:11:00,550 --> 00:10:58,490

if

297

00:11:01,389 --> 00:11:00,560

in here hiding summer yeah he raised his

298

00:11:03,250 --> 00:11:01,399

hand back there was working on the

299

00:11:04,840 --> 00:11:03,260

sample delivery and I think it mostly

300

00:11:06,160 --> 00:11:04,850

works at this point and he's gonna

301  
00:11:08,500 --> 00:11:06,170  
demonstrate it in the field in about a

302  
00:11:10,360 --> 00:11:08,510  
month on board autonomous data

303  
00:11:12,670 --> 00:11:10,370  
classification we've got a group at JPL

304  
00:11:14,769 --> 00:11:12,680  
working on that because as you can tell

305  
00:11:16,750 --> 00:11:14,779  
from the videos we can take way more

306  
00:11:18,519 --> 00:11:16,760  
data than we could possibly send home so

307  
00:11:21,070 --> 00:11:18,529  
we have to have something to evaluate

308  
00:11:22,710 --> 00:11:21,080  
what's the best data to send home super

309  
00:11:25,389 --> 00:11:22,720  
resolution with fancy dyes a

310  
00:11:27,460 --> 00:11:25,399  
polarization we can add full

311  
00:11:28,960 --> 00:11:27,470  
polarization measurements basically

312  
00:11:32,440 --> 00:11:28,970  
using the same technique as we're doing

313  
00:11:34,930 --> 00:11:32,450

for the multi wavelength and one of the

314

00:11:36,639 --> 00:11:34,940

point I want to make is that we only

315

00:11:38,199 --> 00:11:36,649

need about 40 microliters a sample

316

00:11:40,570 --> 00:11:38,209

through the system in order to get

317

00:11:41,680 --> 00:11:40,580

sensitivity down to about 100 particles

318

00:11:46,150 --> 00:11:41,690

per milliliter which is in the

319

00:11:50,199 --> 00:11:46,160

requirement for the Europa Lander other

320

00:11:52,650 --> 00:11:50,209

thing no moving parts basically we

321

00:11:54,550 --> 00:11:52,660

wanted to have it as simple as possible

322

00:11:55,780 --> 00:11:54,560

building flight Hardware is a big pain

323

00:11:58,090 --> 00:11:55,790

the more moving parts you have the

324

00:12:00,550 --> 00:11:58,100

bigger apena does and it's also got very

325

00:12:01,990 --> 00:12:00,560

loose alignment requirements oh I think

326

00:12:03,069 --> 00:12:02,000

that's about it and I just want to leave

327

00:12:05,440 --> 00:12:03,079

you with this side we're having an

328

00:12:11,350 --> 00:12:05,450

imaging workshop for a life detection at

329

00:12:11,360 --> 00:12:15,540

[Music]

330

00:12:37,570 --> 00:12:20,230

any questions sir chris speech so you

331

00:12:39,520 --> 00:12:37,580

clawed well so for Europa you're gonna

332

00:12:41,440 --> 00:12:39,530

get three samples from about the same

333

00:12:47,380 --> 00:12:41,450

place so we don't worry that much of a

334

00:12:50,110 --> 00:12:47,390

cross-contamination between them we can

335

00:12:52,420 --> 00:12:50,120

do a blank so it went after you flush if

336

00:12:54,160 --> 00:12:52,430

there's anything stuck there one of the

337

00:12:55,690 --> 00:12:54,170

nice features of doing everything

338

00:12:57,730 --> 00:12:55,700

numerically is that you can remove

339

00:12:59,880 --> 00:12:57,740

everything numerically and so anything

340

00:13:02,350 --> 00:12:59,890

that's a static error we can basically

341

00:13:05,440 --> 00:13:02,360

just take a picture of and then subtract

342

00:13:08,050 --> 00:13:05,450

in post one of the things that we've

343

00:13:09,640 --> 00:13:08,060

been sort of moving towards as we do all

344

00:13:10,900 --> 00:13:09,650

this work is we're finding out that the

345

00:13:12,640 --> 00:13:10,910

actual optics in it are less and less

346

00:13:15,430 --> 00:13:12,650

and less the better your computer is

347

00:13:17,860 --> 00:13:15,440

that you can have almost a bear detector