Transcript of Mohammed Islam, Sc.D.

Date: July 23, 2026
Case: Samsung Electronics Co., Ltd., et al. -v- Omni MedSci, Inc. (PTAB)

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1 UNITED STATES PATENT AND TRADEMARK OFFICE

_____

2 BEFORE THE PATENT TRIAL AND APPEAL BOARD

3

SAMSUNG ELECTRONICS CO., LTD., et al,

4 Petitioners,

vs.

5 OMNI MEDSCI, INC.,

Patent Owner.

6 _____

7 Case: IPR2025-01252

U.S. Patent No. 11,160,455

8 Case: IPR2025-01250

U.S. Patent No. 9,651,533

9 Case: IPR2025-01251

U.S. Patent No. 10,874,304

10 Case: IPR2025-01254

U.S. Patent No. 12,268,475

11

12 DEPOSITION OF MOHAMMED ISLAM, Sc.D.

13 Thursday, July 23, 2026

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19 Job No.: 642740

20 Pages: 1 - 151

21 Stenographically Reported By:

22 Alison C. Webster, CSR, RPR, RMR, CRR, RDR

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5 Deposition of MOHAMMED ISLAM, Sc.D., produced
6 as a witness at the instance of the Petitioners,
7 and duly sworn, was taken in the above-styled and
8 numbered cause on Thursday, July 23, 2026, from
9 9:19 a.m. to 12:33 p.m. Eastern Time, before Alison
10 C. Webster, RPR, CRR, RMR, RDR, CSR-6266
11 (Michigan); License No. 14559 (California); License
12 No. 084.004953 (Illinois); CSR-12432 (Texas),
13 reported by stenographic method, via
14 videoconference, pursuant to the Federal Rules of
15 Civil Procedure and the provisions stated on the
16 record or attached hereto.
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19
20
21
22

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1 T A B L E O F C O N T E N T S
2
3 Witness Page
4 MOHAMMED ISLAM, Sc.D.
5
6 EXAMINATION
7 BY MR. DAVIS: 6
8
9 E X H I B I T I N D E X
10
11 Exhibit Page
12
13 (Exhibits not offered.)
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1 DEPOSITION OF MOHAMMED ISLAM, Sc.D.
2 Thursday, July 23, 2026
3
4 STENOGRAPHER: The attorneys
5 participating in this deposition and the
6 witness have verified that he is Mohammed
7 Islam, Sc.D. In lieu of an oath administered
8 in person, the witness will visually affirm
9 his testimony in this matter is under penalty
10 of perjury. The parties and their counsel
11 consent to this arrangement and waive any
12 objections to this manner of reporting or
13 admissibility of the transcript.
14 Would counsel please state their
15 appearance and any objections to proceeding in
16 this manner, starting with scheduling counsel.
17 MR. DAVIS: James Davis of Sheppard 09:18:36
18 Mullin for the petitioners. 09:18:40
19 MR. CHRISTOPHER: Good morning. 09:18:41
20 Angelo Christopher of Nixon Peabody, on behalf 09:18:42
21 of patent owner and the witness.
22 STENOGRAPHER: Hearing no objections,

1 Dr. Islam, would you please raise your right
2 hand.
3 Do you swear or affirm the testimony
4 you are about to give in this matter will be
5 the truth, the whole truth, and nothing but
6 the truth?
7 DR. ISLAM: Yes, I do.
8 STENOGRAPHER: Thank you.
9 You may proceed.
10 MOHAMMED ISLAM, Sc.D.,
11 was thereupon called as a witness herein, and
12 after having first been duly sworn to testify
13 to the truth, the whole truth and nothing but
14 the truth, was examined and testified as
15 follows: 09:19:04
16 EXAMINATION 09:19:04
17 BY MR. DAVIS: 09:19:04
18 Q. Can you please state your name? 09:19:04
19 A. Mohammed Nazrul Islam. 09:19:09
20 Q. Dr. Islam, where are you located today? 09:19:10
21 A. I'm in Ann Arbor, Michigan. 09:19:13
22 Q. You understand that you're here testifying 09:19:16

1 based off of declarations you filed or that 09:19:19
2 were filed in IPR 2025-1250, 1251, 1252, and 09:19:21
3 1254? 09:19:30
4 A. I understand I'm here in deposition on the 09:19:32
5 declaration I provided on the IPR cases I 09:19:38
6 believe that you just stated. 09:19:40
7 Q. Did you prepare for this deposition? 09:19:42
8 A. Yes, I did prepare for this deposition. 09:19:50
9 Q. How did you prepare? 09:19:53
10 MR. CHRISTOPHER: Let me just caution 09:19:54
11 the witness not to reveal the substance of any 09:19:56
12 attorney-client communications, but you can 09:19:58
13 answer. 09:19:59
14 A. I read my declaration and the exhibits that 09:20:04
15 were provided. 09:20:10
16 And then, for your information, I 09:20:11
17 have clean, unmarked copies sitting in front 09:20:13
18 of me, in case you have those, as provided by 09:20:15
19 counsel, and I had several meetings with 09:20:18
20 counsel in preparation for this -- for this 09:20:20
21 deposition. 09:20:25
22 BY MR. DAVIS: 09:20:26

1 Q. Who did you meet with? 09:20:26
2 THE WITNESS: Am I allowed to say 09:20:30
3 that, Angelo? 09:20:32
4 MR. CHRISTOPHER: Yes. Do not reveal 09:20:32
5 the substance of any attorney-client 09:20:33
6 communications, but you can reveal the names 09:20:35
7 of the attorneys that you met with. 09:20:36
8 A. The sessions were with Angelo Christopher, 09:20:43
9 who's on here, as well as in some of them, or 09:20:45
10 some parts of them, Jennifer Hayes, also of 09:20:49
11 Nixon Peabody. 09:20:51
12 Q. Did you meet with anyone else? 09:20:53
13 A. No, I did not. 09:20:55
14 Q. You said you have clean copies of something. 09:20:56
15 You have clean copies of what? 09:21:00
16 A. The attorneys have provided me with clean 09:21:04
17 copies of -- and the only thing that's in 09:21:07
18 front of me is the clean copies of the -- 09:21:10
19 what they call Exhibit 2100 declaration, 09:21:12
20 Exhibit 2101, which is one of the exhibits, I 09:21:17
21 guess, all the way through 2107. 09:21:23
22 So it's 2100, the declaration 09:21:27

1 itself, and then there are referenced 09:21:29
2 Exhibits 2101 through 2107. 09:21:38
3 Q. And there's no markings on those? 09:21:40
4 A. No, there are no markings on those. 09:21:42
5 Q. Outside of your meetings with counsel and your 09:21:44
6 review of those papers, did you do anything 09:21:53
7 else to prepare for the deposition today? 09:21:56
8 A. No. I'm sorry, yeah, there was one other 09:22:00
9 thing. I just briefly glanced at the claims 09:22:03
10 in the four patents that are in the IPR. I 09:22:07
11 didn't study them, but I briefly looked at 09:22:12
12 them. 09:22:14
13 Q. Did you do anything else? 09:22:15
14 A. No, I did not. 09:22:17
15 Q. Okay. And, Dr. Islam, I understand this is 09:22:18
16 not your first deposition; is that correct? 09:22:20
17 A. Yes, this is not my first deposition. 09:22:24
18 Q. How many times have you been deposed? 09:22:27
19 A. I don't have a precise number off the top of 09:22:33
20 my head, but it's north of 15 probably. 09:22:36
21 Q. And in each of those depositions, was -- were 09:22:39
22 you the -- strike that. 09:22:46

1 Did those depositions all involve 09:22:51
2 your patents? 09:22:54
3 A. No, not all of the deposition involved my 09:22:58
4 patents. 09:23:01
5 Q. Were you -- were you deposed as an expert in 09:23:03
6 other cases? 09:23:05
7 A. Yes, I was deposed as an expert in other 09:23:07
8 cases. 09:23:10
9 Q. About how many times have you been deposed on 09:23:10
10 your own patents? 09:23:15
11 A. Again, I don't know the precise number, but 09:23:20
12 north of -- north of ten, at least. 09:23:22
13 Q. And how many times have you been deposed as an 09:23:26
14 expert in a case? 09:23:29
15 A. I'm sorry, say again, please? 09:23:30
16 Q. How many times have you been deposed as an 09:23:32
17 expert in the case? 09:23:34
18 A. Expert -- oh, in a separate case? Again, 09:23:37
19 somewhere on the order of three to five 09:23:39
20 times, I think, from -- 09:23:41
21 Q. How many times have you -- 09:23:41
22 A. -- my memory. 09:23:44

1 Q. Apologies, I can't tell when you're finished 09:23:46
2 talking -- 09:23:48
3 A. I'm sorry. 09:23:48
4 Q. -- and I'll try not to talk over you. My 09:23:48
5 apologies. 09:23:51
6 A. That's all right. 09:23:51
7 Q. How many times have you been retained as an 09:23:52
8 expert in a patent case? 09:23:56
9 A. It's been a while, but, again, going from 09:24:01
10 memory -- I haven't reviewed that document -- 09:24:04
11 but probably somewhere, again, three to five 09:24:07
12 times. 09:24:10
13 Q. So -- as I'm sure you're used to, if you can 09:24:11
14 let me know if you don't understand the 09:24:19
15 question I'm asking, and I appreciate that. 09:24:21
16 A. Okay. Thank you. 09:24:26
17 Q. And when you answer, please answer verbally 09:24:27
18 and clearly, rather than just nodding, so that 09:24:29
19 we have a clear transcript. Can you do that? 09:24:32
20 A. Yes, I will try to respond verbally. 09:24:34
21 Q. And if you need a break, just let me know. I 09:24:37
22 do ask that if there's a pending question, we 09:24:43

1 get that resolved and answered before we go 09:24:45
2 off record; is that fair? 09:24:48
3 A. Yes, that's fair. 09:24:49
4 Q. Where are you sitting now? 09:24:52
5 A. I am sitting in my home office in Ann Arbor, 09:24:54
6 Michigan. 09:24:58
7 Q. Is there anyone in the office or room with 09:24:58
8 you? 09:25:03
9 A. No, there is no one in my room, and I've also 09:25:03
10 closed the doors to try to reduce any 09:25:05
11 background noise. 09:25:08
12 Q. Thank you. Other than Zoom, do you have any 09:25:09
13 other applications open on your computer? 09:25:15
14 A. I -- as per the request, I do have a -- 09:25:18
15 what's it called -- a file whatever, file 09:25:23
16 thing that has an open file so that I can put 09:25:28
17 the deposition exhibits in. 09:25:30
18 Q. Anything else? 09:25:33
19 A. No, but when I click on those, of course 09:25:35
20 either a PDF or a Word doc -- window will 09:25:39
21 open. 09:25:42
22 Q. Yes. 09:25:42

1 A. My window, by the way, is on -- on my right, 09:25:43
2 which, I guess, will look backwards left on 09:25:47
3 you. 09:25:48
4 Q. Thanks, I appreciate that. 09:25:48
5 Yeah, I would just ask that you not 09:25:50
6 open up any other applications beyond Zoom or 09:25:52
7 Adobe or whatever you need to open up the 09:25:55
8 exhibits. 09:25:57
9 A. Okay. Thank you. 09:25:58
10 Q. You have an SC degree; is that correct? Sc.D. 09:26:04
11 degree, excuse me. 09:26:08
12 A. Yes, Sc.D., standing for doctor of science. 09:26:09
13 I have a bachelor's, a master's, and an Sc.D. 09:26:13
14 degree from Massachusetts Institute of 09:26:16
15 Technology, or MIT. 09:26:20
16 Q. Are you familiar with physiological monitoring 09:26:21
17 devices? 09:26:27
18 MR. CHRISTOPHER: Objection to form. 09:26:31
19 A. I am aware of certain types of physiological 09:26:32
20 measurement devices. 09:26:40
21 BY MR. DAVIS: 09:26:42
22 Q. What are common types of physiological 09:26:43

1 monitoring devices? 09:26:45
2 MR. CHRISTOPHER: Objection to form. 09:26:47
3 A. Well, again, there are many types of 09:26:48
4 physiological measurement devices. Myself, I 09:26:53
5 am an optics and photonics professor and an 09:26:59
6 expert in light-based matter, so most of my 09:27:03
7 experience are on light-based physiological 09:27:09
8 measurements. Having said that, of course, 09:27:12
9 there's many other, kind of, physiological 09:27:15
10 measurements that can be done. 09:27:18
11 BY MR. DAVIS: 09:27:20
12 Q. How many patents have you applied for? 09:27:20
13 A. I've lost count, but somewhere on the order 09:27:27
14 of about 215 U.S. patents. 09:27:29
15 Q. Was that 250, 5-0, or 215, 1-5? 09:27:33
16 A. 2-1-5, I'm sorry. 09:27:40
17 Q. And on those 215 patents, are you the sole 09:27:46
18 inventor on all of them? 09:27:53
19 MR. CHRISTOPHER: Objection. Scope. 09:27:55
20 A. On -- no, not on all 215. I'm sorry, to be 09:27:57
21 clear, I'm not the sole inventor on all 09:28:11
22 215 -- 09:28:13

1 BY MR. DAVIS: 09:28:13
2 Q. Okay. 09:28:13
3 A. -- or thereabouts number of patents. 09:28:14
4 Q. So you have co-inventors on some of your 09:28:16
5 patents? 09:28:19
6 MR. CHRISTOPHER: Same objection. 09:28:19
7 A. I do have -- 09:28:19
8 MR. CHRISTOPHER: Go ahead. 09:28:25
9 A. I do have co-inventors on some of the 09:28:25
10 patents, that is correct. 09:28:27
11 BY MR. DAVIS: 09:28:32
12 Q. About what percentage? 09:28:32
13 MR. CHRISTOPHER: Same objection. 09:28:34
14 A. You know, again, I haven't reviewed that. I 09:28:39
15 can guess. Again, it would just be purely 09:28:47
16 conjecture at this point. Probably about a 09:28:49
17 fifth of them have co-inventors, but, again, 09:28:51
18 that's just a rough number. I would have to 09:28:53
19 review that to answer that more precisely. 09:28:55
20 BY MR. DAVIS: 09:28:58
21 Q. Have you taken what's called the Patent Bar? 09:29:03
22 A. Yes, I have taken the USPTO's Patent Bar 09:29:09

1 exam. 09:29:14
2 Q. When did you take that? 09:29:14
3 A. Again, you're asking me to go stretch back in 09:29:24
4 my memory, but the -- it would be on the 09:29:27
5 order of 2003 or 2004, somewhere around that 09:29:30
6 time. 09:29:36
7 Q. How did you prepare to take the Patent Bar? 09:29:37
8 MR. CHRISTOPHER: Objection to form. 09:29:42
9 A. Well, you know, most of the preparation, of 09:29:50
10 course, is to go through and review the MPEP, 09:29:52
11 the Manual of Patent Examination Procedures. 09:29:57
12 That's the basis of the U.S. Patent Bar exam. 09:30:01
13 And so going through that, reviewing it, 09:30:07
14 taking old bar exams. And, in fact, I also 09:30:12
15 teach a course on patents because the best 09:30:18
16 way to learn is to teach it. 09:30:20
17 BY MR. DAVIS: 09:30:23
18 Q. Did you do anything else to prepare to take 09:30:29
19 the Patent Bar? 09:30:31
20 A. Yeah. I think I took one of the prep courses 09:30:32
21 as well. I forget the name of it. But, you 09:30:35
22 know, again, there's a lot of Patent Bar 09:30:41

1 exams, basically reviewing those. 09:30:43
2 Q. You said you teach a course on patents. Did 09:30:44
3 you teach that course before you took the 09:30:49
4 Patent Bar? 09:30:52
5 A. Again, going from memory, I taught that 09:30:57
6 course the year I was taking the Patent Bar 09:30:59
7 exam. 09:31:01
8 Q. So would you consider yourself to be a patent 09:31:09
9 agent? 09:31:12
10 MR. CHRISTOPHER: Objection to form. 09:31:13
11 A. I have registration number with the 09:31:16
12 U.S. Patent Office that says I am a patent 09:31:20
13 agent. 09:31:23
14 BY MR. DAVIS: 09:31:34
15 Q. As part of studying for the Patent Bar, did 09:31:34
16 you have to become familiar with the rules and 09:31:36
17 requirements for patent prosecution before the 09:31:38
18 U.S. Patent and Trademark Office? 09:31:39
19 A. Yes. In preparation for the Patent Bar, as I 09:31:44
20 said, the Patent Bar is based on the MPEP, 09:31:51
21 and that has -- if I understand your question 09:31:55
22 correctly, the rules for prosecution, is 09:31:59

1 that -- was that your question? I'm sorry. 09:32:04
2 Q. You've prosecuted patents yourself; is that 09:32:09
3 correct? 09:32:11
4 MR. CHRISTOPHER: Objection to form. 09:32:13
5 A. I am involved in patent prosecution, but all 09:32:17
6 of my patent prosecution are done by 09:32:21
7 attorneys. 09:32:23
8 BY MR. DAVIS: 09:32:32
9 Q. Have you had any interaction directly with the 09:32:34
10 patent office yourself? 09:32:37
11 MR. CHRISTOPHER: Objection to form. 09:32:38
12 A. I have had some interactions with the patent 09:32:44
13 office directly. 09:32:52
14 BY MR. DAVIS: 09:32:52
15 Q. What were those? 09:32:53
16 A. In at least -- again, going from memory, at 09:32:55
17 least two occasions I was invited to give 09:33:00
18 talks at what are called -- what was at least 09:33:07
19 called "tech days" at the patent office. So 09:33:12
20 I think at least twice I was invited to give 09:33:14
21 seminars at the tech days. 09:33:19
22 Q. Have you yourself made any filings with the 09:33:20

1 patent office as a patent agent? 09:33:27
2 MR. CHRISTOPHER: Objection to form. 09:33:32
3 A. No. All of my filings -- let me be clear. I 09:33:33
4 don't -- like I said, I don't remember 09:33:42
5 exactly on whether it ever has my 09:33:44
6 registration number on them, but all filings 09:33:49
7 with the patent office are done through 09:33:52
8 attorneys. What I don't remember is if any 09:33:54
9 of them had on the submitted documents. I 09:34:00
10 mean, they obviously have my name as 09:34:03
11 inventor, but -- and filed on my behalf, but 09:34:05
12 I don't remember if it ever had, for example, 09:34:07
13 my registration number cited on there. 09:34:09
14 BY MR. DAVIS: 09:34:11
15 Q. With respect to the patents involved in these 09:34:16
16 four IPRs, were you involved in prosecuting 09:34:20
17 any of those patents? 09:34:24
18 MR. CHRISTOPHER: Let me just caution 09:34:25
19 the witness, do not reveal the substance of 09:34:26
20 any communications you may have had with 09:34:28
21 attorneys during prosecution, but you can -- 09:34:31
22 you can answer counsel's question "yes" or 09:34:34

1 "no" whether you were involved. 09:34:36
2 A. Yes, I'm involved, but, again, all 09:34:37
3 interactions with the patent office are 09:34:45
4 through counsel. 09:34:47
5 BY MR. DAVIS: 09:34:56
6 Q. So do you recall whether you acted as a patent 09:34:56
7 agent in prosecuting any of the four patents 09:34:58
8 at issue in these IPRs? 09:35:00
9 MR. CHRISTOPHER: Objection to form. 09:35:05
10 And I'll give you the same caution 09:35:06
11 about revealing the substance of any 09:35:07
12 attorney-client communications. 09:35:09
13 A. As I said, all interactions with the patent 09:35:15
14 office are done through my prosecuting 09:35:17
15 attorneys. 09:35:20
16 I'm sorry, did I answer your 09:35:36
17 question? 09:35:38
18 BY MR. DAVIS: 09:35:39
19 Q. My question was whether you acted as a patent 09:35:40
20 agent in prosecuting any of the four patents 09:35:43
21 at issue in these IPRs. 09:35:46
22 MR. CHRISTOPHER: Same objection. 09:35:47

1 And I'll give you the same caution 09:35:48
2 about communications with counsel. 09:35:49
3 A. If your question is did I ever interact 09:35:55
4 directly with the patent office, the answer 09:35:58
5 is no. I guess I don't know what you mean as 09:36:00
6 a patent agent interacting with the patent 09:36:02
7 office. 09:36:04
8 BY MR. DAVIS: 09:36:17
9 Q. With respect to the four patents that are at 09:36:17
10 issue in these IPRs, are you still prosecuting 09:36:20
11 patents in that family? 09:36:25
12 MR. CHRISTOPHER: Objection to form. 09:36:28
13 Also scope. 09:36:29
14 And, again, let me just caution the 09:36:29
15 witness, don't reveal the substance of any 09:36:32
16 communications with counsel -- prosecuting 09:36:35
17 counsel with respect to those applications. 09:36:37
18 A. I'm sorry, could you repeat your question, 09:36:43
19 please? 09:36:45
20 BY MR. DAVIS: 09:36:48
21 Q. Yes. I said, with respect to the four patents 09:36:48
22 that are at issue in these IPRs, are you still 09:36:50

1 prosecuting patents in that family? 09:36:53
2 MR. CHRISTOPHER: Same objections. 09:36:55
3 A. So if I might ask for clarification. What do 09:37:00
4 you mean by "family," I guess? Just to be 09:37:07
5 clear. I want to make sure I understand. 09:37:09
6 BY MR. DAVIS: 09:37:11
7 Q. Are you familiar with the concept of a patent 09:37:12
8 family? 09:37:16
9 A. I am generally, but if you could be more 09:37:18
10 specific on what you're asking just so I can 09:37:20
11 make sure to answer properly. 09:37:24
12 Q. What is a patent family? 09:37:26
13 A. As I understand it, a patent family would be 09:37:31
14 if I have a certain patent, it may have what 09:37:33
15 we call parents, for example, it claims 09:37:37
16 priority to, and it may also have something 09:37:41
17 like children, which might be, as an example, 09:37:43
18 a continuation or a divisional. 09:37:46
19 That's my -- how I describe a family 09:37:50
20 to be, I guess, in the patent world. 09:37:52
21 Q. With respect to the four patents that are at 09:37:54
22 issue in these IPRs, are you still prosecuting 09:37:57

1 patents in that family? 09:38:00
2 MR. CHRISTOPHER: Same objections. 09:38:03
3 Form. Scope. 09:38:04
4 And, again, I'll just caution you not 09:38:05
5 to reveal any communications with prosecution 09:38:07
6 counsel. 09:38:09
7 A. Again, I'm not quite sure I understand your 09:38:17
8 question, but there are patents that are 09:38:19
9 being prosecuted that are within the scope of 09:38:22
10 the same family or at least have parts of the 09:38:28
11 spec that are the same as these four patents. 09:38:31
12 BY MR. DAVIS: 09:38:39
13 Q. Do you know about how many patents have been 09:38:39
14 issued that are related to the four patents at 09:38:41
15 issue in these IPRs? 09:38:47
16 MR. CHRISTOPHER: Object to form. 09:38:51
17 A. I do not, off the top of my head, know how 09:38:52
18 many patents are, as you describe, in the 09:39:01
19 family of these four patents. 09:39:04
20 BY MR. DAVIS: 09:39:06
21 Q. Approximately, do you know? 09:39:07
22 A. Yeah, probably approximately somewhere -- 09:39:18

1 again, related to these four patents, we're 09:39:25
2 talking about the '533, '304, '455, and '475 09:39:27
3 patents. Correct? 09:39:32
4 Q. Yes. 09:39:34
5 A. Yeah. Yeah, there may be on the order of 09:39:35
6 maybe, again, approximate number, 30-ish 09:39:44
7 patents or patents pending. 09:39:48
8 Q. Does increasing light intensity in a wearable 09:40:00
9 device always improve the signal-to-noise 09:40:03
10 ratio? 09:40:07
11 MR. CHRISTOPHER: Objection to form 09:40:07
12 and scope. 09:40:08
13 A. In general, increasing light intensity 09:40:16
14 improves signal-to-noise ratio. Basically, 09:40:20
15 when you're increasing light intensity you're 09:40:25
16 increasing the signal level, and so long as 09:40:27
17 the noise level doesn't proportionally 09:40:31
18 increase, in general, it will increase 09:40:34
19 signal-to-noise ratio. 09:40:40
20 BY MR. DAVIS: 09:40:42
21 Q. So does increasing light intensity in a 09:40:43
22 wearable device always improve the 09:40:46

1 signal-to-noise ratio? 09:40:47
2 MR. CHRISTOPHER: Objection to form 09:40:48
3 and scope. 09:40:48
4 A. As I said, in general it increases the 09:40:52
5 signal-to-noise ratio, but, no, it doesn't 09:40:55
6 always have to. 09:40:56
7 BY MR. DAVIS: 09:41:01
8 Q. Prior to your patents, was it known in the 09:41:01
9 field to increase the light intensity -- 09:41:03
10 excuse me. 09:41:06
11 Prior to your patents, was it known 09:41:06
12 in the field to increase light intensity in 09:41:09
13 wearable devices? 09:41:11
14 MR. CHRISTOPHER: Objection to form 09:41:14
15 and scope. 09:41:15
16 A. I'm sorry, could you repeat that question? 09:41:17
17 BY MR. DAVIS: 09:41:19
18 Q. Prior to your patents, was it known in the 09:41:21
19 field to increase light intensity in wearable 09:41:24
20 devices? 09:41:29
21 MR. CHRISTOPHER: Same objections. 09:41:29
22 A. I'm not sure if -- I'm sorry, I'm not sure if 09:41:36

1 you're asking me an obvious question. In a 09:41:39
2 wearable device, if I have a light source 09:41:42
3 there will presumably be times it's off and 09:41:43
4 times it's on; otherwise, your battery is 09:41:46
5 going to run out completely, so -- the 09:41:49
6 wearable device, unless it wants to run the 09:41:51
7 battery out completely, will always have a 09:41:55
8 change in light intensity. 09:41:57
9 Is that what your question is? 09:41:59
10 BY MR. DAVIS: 09:42:03
11 Q. Prior to your patents, was it known in the 09:42:04
12 field to increase light intensity in wearable 09:42:05
13 devices to improve the signal-to-noise ratio? 09:42:10
14 MR. CHRISTOPHER: Objection to form 09:42:14
15 and scope. 09:42:15
16 A. Again, I'm not sure you're giving me the 09:42:16
17 context. Could you be more specific about 09:42:19
18 your context of that question? 09:42:21
19 BY MR. DAVIS: 09:42:24
20 Q. What context do you need? 09:42:27
21 A. Increasing light intensity to increase 09:42:31
22 signal-to-noise ratio of what, I guess? 09:42:34

1 Q. Are you familiar with the concept of 09:42:41
2 increasing light intensity to improve 09:42:43
3 signal-to-noise ratio? 09:42:45
4 A. Well, again, I'm asking, give me a specific 09:42:48
5 context if you might, or I can give you a 09:42:53
6 specific context if you'd like to answer that 09:42:55
7 question. 09:42:56
8 Q. Can you answer my question? Are you familiar 09:42:58
9 with the concept of increasing light intensity 09:43:00
10 to improve signal-to-noise ratio? 09:43:02
11 MR. CHRISTOPHER: Objection to form. 09:43:05
12 A. Again, I'm generally familiar with the 09:43:06
13 concept but, again, that can't be answered 09:43:10
14 without giving a proper context. So, for 09:43:13
15 example, if you'd like, we can pin this down 09:43:16
16 to a field of what's called spectroscopy. 09:43:19
17 BY MR. DAVIS: 09:43:23
18 Q. Okay. So in the field of spectroscopy, prior 09:43:24
19 to your patents, was it known in that field to 09:43:31
20 increase the light intensity in wearable 09:43:33
21 devices to improve signal-to-noise ratio? 09:43:36
22 MR. CHRISTOPHER: Objection to form 09:43:39

1 and scope. 09:43:39
2 A. I'm sorry, you just crossed fields, so -- you 09:43:42
3 included something in that question that 09:43:45
4 wasn't in my -- you said "spectroscopy" and 09:43:47
5 "wearables." Which do you mean? 09:43:52
6 BY MR. DAVIS: 09:43:53
7 Q. Okay. So you consider spectroscopy and 09:43:54
8 wearables to be two different fields? 09:43:57
9 A. Again, are you speaking to spectroscopy or 09:44:04
10 are you speaking to wearables? Let me just 09:44:07
11 be -- let me explain my confusion on that. 09:44:09
12 So when I think about spectroscopy, 09:44:11
13 I'm thinking about a -- as an example, a 09:44:14
14 laboratory setting where I have a big laser, 09:44:17
15 I have some sample under test, I have a 09:44:20
16 receiver, et cetera, et cetera. 09:44:22
17 When I think about a wearable, I'm 09:44:23
18 thinking about something that I might put on 09:44:25
19 my wrist or my ear or something. 09:44:27
20 And so in one instance, I use 09:44:30
21 "spectroscopy" generally. When I think about 09:44:32
22 spectroscopy, I think about a laboratory 09:44:35

1 setting on a lab table. When I think about a 09:44:37
2 wearable, I think about something on a wrist 09:44:41
3 or an ear or some other part of your body. 09:44:43
4 So that's why I say if you could 09:44:45
5 clarify, that would be helpful. 09:44:46
6 Q. Let's talk about wearables, then. 09:44:48
7 Prior to your patents, was it known 09:44:54
8 in the field to increase the light intensity 09:44:56
9 in wearable devices to improve signal-to-noise 09:44:58
10 ratio? 09:45:00
11 MR. CHRISTOPHER: Objection to form 09:45:01
12 and scope. 09:45:01
13 A. In the field of wearables, where, again, by 09:45:05
14 "wearables" we're talking about something 09:45:09
15 that -- to be specific, when I say 09:45:10
16 "wearables," I'm talking about something that 09:45:13
17 you put on a wrist or ear, as an example. I 09:45:14
18 actually don't know whether it was known or 09:45:17
19 whether people increased light intensity to 09:45:21
20 increase signal-to-noise ratio. I don't know 09:45:24
21 the answer to that. 09:45:26
22 BY MR. DAVIS: 09:45:27

1 Q. In the field of optical sensing, prior to your 09:45:30
2 patents, was it known to increase light 09:45:35
3 intensity to improve signal-to-noise ratio? 09:45:42
4 MR. CHRISTOPHER: Objection to form 09:45:45
5 and scope. 09:45:46
6 A. Well, again, optical sensing is a fairly 09:45:46
7 broad and vague field. 09:45:54
8 Let me be more specific. 09:45:56
9 In the field of spectroscopy, as I 09:45:58
10 defined where you had the light source, a 09:46:07
11 sample under test, a receiver on a lab table, 09:46:08
12 in that context, it was known that 09:46:10
13 improving -- increasing light intensity would 09:46:13
14 improve signal-to-noise ratio, or could, in 09:46:19
15 general. 09:46:20
16 BY MR. DAVIS: 09:46:24
17 Q. Is spectroscopy part of optical sensing, as a 09:46:25
18 field? 09:46:32
19 A. Again, I don't know if we're getting into 09:46:44
20 semantics, but yes, I would say in general. 09:46:46
21 Optical sensing is extremely broad, right, 09:46:49
22 you know. If I am looking at you right now 09:46:52

1 in Zoom, I am doing an optical sensing. So, 09:46:54
2 you know, to draw an analogy, if I touch 09:47:01
3 something, I'm doing a touch sensing. With 09:47:04
4 my -- if I'm doing something with my eye, 09:47:05
5 it's optical sensing. So that's extremely 09:47:08
6 broad. 09:47:11
7 Spectroscopy is tying it -- it's a 09:47:12
8 subset of that, if you like, where, as I 09:47:14
9 said, in the laboratory setting, you have a 09:47:15
10 light source sample under a test, receiver, 09:47:17
11 and probably some processor associated with 09:47:18
12 that. 09:47:20
13 But, again, I could describe my 09:47:20
14 looking at you as an optical sensing, and so 09:47:22
15 optical sensing is a very broad term. 09:47:27
16 Q. If a user turns up the light intensity on a 09:47:29
17 wearable device, does that improve the 09:47:41
18 signal-to-noise ratio? 09:47:42
19 MR. CHRISTOPHER: Objection to form 09:47:43
20 and scope. 09:47:44
21 A. I don't know the answer to that question 09:47:51
22 because at least in the wearable devices I 09:47:52

1 have, I don't -- I, as the user, don't have a 09:47:54
2 way to adjust the light intensity. There is 09:47:58
3 no knob that says, increase light intensity, 09:48:02
4 for example, on my -- I'm wearing an Apple 09:48:05
5 Watch. It doesn't have any knob that says, 09:48:08
6 increase light intensity. 09:48:11
7 BY MR. DAVIS: 09:48:13
8 Q. If a watch has two different settings, one 09:48:19
9 with a lower light intensity and one with a 09:48:29
10 higher light intensity on a wearable device, 09:48:34
11 would moving from the lower light intensity to 09:48:36
12 the higher light intensity improve the 09:48:40
13 signal-to-noise ratio? 09:48:42
14 MR. CHRISTOPHER: Same objections. 09:48:43
15 A. So I guess I -- let me just say the premise 09:48:48
16 of that question is not known to me. In 09:49:00
17 other words, I do not know of any wearable 09:49:02
18 device that has a low light intensity and a 09:49:04
19 high light intensity setting for the 09:49:08
20 physiological measurements, for example. But 09:49:09
21 if it had so, again, in general, increasing 09:49:11
22 light intensity would improve the 09:49:17

1 signal-to-noise ratio. 09:49:19
2 But, again, I know of no -- to my 09:49:20
3 knowledge, there's no -- I do not know of a 09:49:23
4 wearable device that has a option of low 09:49:25
5 light intensity or high light intensity. 09:49:31
6 BY MR. DAVIS: 09:49:34
7 Q. How would you determine whether a 09:49:34
8 signal-to-noise ratio has increased? 09:49:36
9 MR. CHRISTOPHER: Objection. Scope 09:49:37
10 and form. 09:49:38
11 A. I'm sorry, could you repeat your question 09:49:42
12 again? 09:49:44
13 BY MR. DAVIS: 09:49:44
14 Q. How would you determine whether a 09:49:45
15 signal-to-noise ratio has been increased? 09:49:46
16 MR. CHRISTOPHER: Objection. Scope 09:49:49
17 and form. 09:49:52
18 A. Could we put that into a context so I can 09:49:53
19 imagine how to do that measurement? 09:49:56
20 BY MR. DAVIS: 09:49:59
21 Q. In a wearable device, how do you determine 09:49:59
22 whether a signal-to-noise ratio has been 09:50:02

1 increased? 09:50:03
2 MR. CHRISTOPHER: Objection. Scope. 09:50:05
3 A. Well, I can think of an experiment to do 09:50:06
4 that. Is that what you're asking? 09:50:12
5 BY MR. DAVIS: 09:50:17
6 Q. I'm asking, in a wearable device, how would 09:50:17
7 you determine whether a signal-to-noise ratio 09:50:20
8 has been increased? 09:50:22
9 MR. CHRISTOPHER: Objection. Form. 09:50:24
10 Scope. 09:50:25
11 A. Well, I, as a user, do not get information -- 09:50:27
12 just simply -- again, let me take the -- let 09:50:34
13 me be specific. 09:50:36
14 I happen to be wearing an Apple 09:50:37
15 Watch so it will be specific to that. And 09:50:40
16 the Apple Watch, it does a measurement, it 09:50:43
17 gives me a number. It doesn't give me a 09:50:45
18 signal-to-noise ratio out of it. 09:50:47
19 So just as a user, I have no way to 09:50:50
20 determine the signal-to-noise ratio. I can 09:50:53
21 imagine experiments I could do in a 09:50:59
22 laboratory setting where I -- if I had to 09:51:01

1 take apart and I had access to everything, 09:51:04
2 but as the user, I get a number. 09:51:06
3 BY MR. DAVIS: 09:51:08
4 Q. In a laboratory setting, how would you 09:51:09
5 determine whether a signal-to-noise ratio has 09:51:16
6 been increased in a wearable device? 09:51:19
7 MR. CHRISTOPHER: Objection. Outside 09:51:22
8 the scope. 09:51:26
9 A. Right. So, again, if we could, as an 09:51:26
10 example, carry out like a Gedankenexperiment. 09:51:34
11 Let's say that I had a wearable device that's 09:51:38
12 been taken apart and I have access to all of 09:51:41
13 the inputs and outputs coming from the 09:51:43
14 circuitry, I would have to define something 09:51:47
15 that's the signal, and that might be, for 09:51:52
16 example, you know, the measurement of 09:51:57
17 whatever you care about, and I would have to 09:51:59
18 have something describing the noise as -- 09:52:03
19 and, again, that noise might be, for example, 09:52:08
20 the signal when the light is off or something 09:52:10
21 like that. Or, you know, when you're not 09:52:12
22 wearing it or something. 09:52:14

1 And then I'd have to independently 09:52:17
2 measure that signal, and I have to 09:52:19
3 independently measure that noise and take 09:52:22
4 the -- divide those two to get the 09:52:24
5 signal-to-noise ratio. 09:52:26
6 But as I said, in most wearables, 09:52:27
7 the user doesn't have access to the signal 09:52:30
8 and the noise. 09:52:34
9 Q. So once you found that signal-to-noise ratio, 09:52:35
10 how would you determine whether it's been 09:52:38
11 improved? 09:52:40
12 MR. CHRISTOPHER: Objection. Scope. 09:52:42
13 A. Well, again, I'm going through sort of an 09:52:47
14 Gedankenexperiment on this. The way I would 09:52:50
15 do it in the laboratory is I would have some 09:52:54
16 sort of knob on increasing the noise level, 09:52:58
17 as an example. And then if I know how much 09:53:05
18 I've increased the noise level by, I can then 09:53:09
19 see whether the signal-to-noise ratio has 09:53:11
20 proportionately changed, as an example. 09:53:12
21 Again, giving just one example of 09:53:16
22 how you might measure that. 09:53:17

1 BY MR. DAVIS: 09:53:19
2 Q. How do you tell if increasing light intensity 09:53:21
3 improved the signal-to-noise ratio in a 09:53:24
4 wearable device? 09:53:26
5 MR. CHRISTOPHER: Objection to form. 09:53:27
6 Outside the scope. 09:53:27
7 A. As I said, as a user of the device, I either 09:53:29
8 get a reading or I don't get a reading. 09:53:40
9 There is nothing on something like the smart 09:53:45
10 watches that give a signal-to-noise ratio 09:53:50
11 number. So as a user, I don't see that. I 09:53:54
12 either get a reading or I don't. 09:53:58
13 BY MR. DAVIS: 09:54:00
14 Q. In a laboratory setting, how do you tell if 09:54:00
15 increasing light intensity improved the 09:54:03
16 signal-to-noise ratio in a wearable device? 09:54:06
17 MR. CHRISTOPHER: Objection. Form. 09:54:10
18 Outside the scope. 09:54:11
19 A. Again, you're asking me a hypothetical 09:54:11
20 question, but as an example, again, a 09:54:18
21 Gedankenexperiment, if I have control over, 09:54:21
22 as an example, the noise level, and I know 09:54:27

1 what the noise level is and I can keep that 09:54:29
2 fixed, then -- and I adjust the signal level. 09:54:32
3 And, again, so long as I can measure 09:54:37
4 the noise level and I can measure the signal 09:54:40
5 level, I can increase the light intensity of 09:54:42
6 the -- again, assuming I have adjustment of 09:54:46
7 the light intensity. I can then see 09:54:48
8 whether -- how that is affecting and whether 09:54:50
9 it's increasing the signal-to-noise level. 09:54:55
10 But it has to be a very controlled 09:54:56
11 environment in the lab where, again, I have 09:54:58
12 control over the signal level and the noise 09:55:00
13 level. 09:55:02
14 Q. Does increasing pulse rate in a wearable 09:55:04
15 device always improve the signal-to-noise 09:55:08
16 ratio? 09:55:10
17 MR. CHRISTOPHER: Objection. Form 09:55:10
18 and scope. 09:55:11
19 A. In general, increasing the -- I'm sorry, did 09:55:14
20 you say repetition? Right? What did you 09:55:21
21 say? Pulse rate, or... 09:55:23
22 BY MR. DAVIS: 09:55:24

1 Q. Does increasing pulse rate in a wearable 09:55:24
2 device always improve the signal-to-noise 09:55:26
3 ratio? 09:55:28
4 MR. CHRISTOPHER: Same objections. 09:55:34
5 A. Again, just to be specific, I'm gonna say -- 09:55:34
6 when I say "pulse rate," I'm gonna assume the 09:55:36
7 pulse repetition rate. But, in general, 09:55:38
8 increasing the pulse repetition rate 09:55:44
9 increases the signal-to-noise ratio because 09:55:50
10 you're giving more photons, basically, to the 09:55:52
11 detector. 09:55:55
12 BY MR. DAVIS: 09:55:58
13 Q. Does increasing pulse rate in a wearable 09:55:59
14 device always improve the signal-to-noise 09:56:01
15 ratio? 09:56:05
16 MR. CHRISTOPHER: Same objections. 09:56:05
17 A. Again, in general, increasing the pulse 09:56:11
18 repetition rate does increase the 09:56:14
19 signal-to-noise ratio, but it doesn't always 09:56:16
20 have to. 09:56:17
21 BY MR. DAVIS: 09:56:21
22 Q. What are instances where increasing the pulse 09:56:21

1 rate in a wearable device would not improve 09:56:24
2 the signal-to-noise ratio? 09:56:30
3 MR. CHRISTOPHER: Objection to scope. 09:56:31
4 A. Again, you'd have to be more specific, but as 09:56:32
5 an example, two instances I can think of. 09:56:37
6 One would be if the detector saturated, in 09:56:40
7 which case it would not improve the 09:56:46
8 signal-to-noise ratio. 09:56:48
9 Another would be if you have -- if 09:56:49
10 the light source itself, as you increase the 09:56:51
11 repetition rate, degrades the output somehow, 09:56:55
12 whether it be -- or higher noise level from 09:56:58
13 the light source itself or maybe the 09:57:03
14 intensity goes down because the pulse rate's 09:57:05
15 gone up and then it can't deliver enough 09:57:08
16 power. 09:57:10
17 So, again, the -- there's -- there 09:57:10
18 have to be assumptions about the light source 09:57:13
19 and the detector to make sure that it's 09:57:15
20 improving signal-to-noise ratio. 09:57:19
21 BY MR. DAVIS: 09:57:20
22 Q. What are instances where increasing the light 09:57:20

1 intensity in a wearable device would not 09:57:24
2 improve the signal-to-noise ratio? 09:57:27
3 MR. CHRISTOPHER: Objection. Form 09:57:28
4 and scope. 09:57:29
5 A. So, again, similar to what we talked about 09:57:33
6 for increasing pulse repetition rate, 09:57:37
7 increasing the light intensity does not 09:57:39
8 always have to lead to improvement of 09:57:41
9 signal-to-noise ratio. Again, in general, it 09:57:45
10 does. But, again, one example would be if 09:57:46
11 the detector gets saturated and increasing 09:57:49
12 the light intensity would not increase 09:57:53
13 signal-to-noise ratio. 09:57:55
14 But, again, in general, if you're 09:57:57
15 operating in the linear regime of the 09:57:59
16 detector, increasing the light intensity does 09:58:01
17 improve the signal-to-noise ratio. 09:58:07
18 BY MR. DAVIS: 09:58:08
19 Q. Can you think of any other examples where 09:58:08
20 increasing the light intensity in a wearable 09:58:11
21 device would not improve the signal-to-noise 09:58:13
22 ratio? 09:58:14

1 MR. CHRISTOPHER: Objection. Scope. 09:58:15
2 A. I'm sure there are, but sitting here, I'd 09:58:17
3 have to think about that more. I don't -- 09:58:25
4 off the top of my head, don't have an answer 09:58:30
5 to that, but I'm sure there are other 09:58:32
6 instances. 09:58:34
7 BY MR. DAVIS: 09:58:34
8 Q. If noise is increased at the same time that 09:58:38
9 light intensity is increased, would the 09:58:42
10 signal-to-noise ratio improve -- 09:58:46
11 MR. CHRISTOPHER: Objection to form. 09:58:49
12 BY MR. DAVIS: 09:58:50
13 Q. -- in a wearable device? Excuse me. 09:58:51
14 MR. CHRISTOPHER: Sorry. Form and 09:58:53
15 scope. 09:58:54
16 A. So, again, in your hypothetical question, if 09:58:58
17 you had a light source where, when you 09:59:01
18 increase the light intensity, the noise level 09:59:04
19 increased proportionately, and let's say you 09:59:06
20 double the signal and you double the noise at 09:59:10
21 the same time, then it would be the same 09:59:13
22 signal-to-noise ratio because the signal 09:59:16

1 doubled and the noise doubled, and so the 09:59:18
2 ratio stayed the same. 09:59:20
3 So, again, if I understood your 09:59:22
4 question, if the light source has where the 09:59:24
5 noise level goes up proportional to the 09:59:29
6 signal, it may not improve the 09:59:31
7 signal-to-noise ratio. 09:59:33
8 Did I understand your question 09:59:34
9 correctly? I'm sorry. 09:59:35
10 BY MR. DAVIS: 09:59:37
11 Q. If noise is increased at the same time that 09:59:38
12 pulse rate is increased in a wearable device, 09:59:41
13 would that improve the signal-to-noise ratio? 09:59:44
14 MR. CHRISTOPHER: Objection. Form 09:59:47
15 and scope. 09:59:48
16 A. Again, in your hypothetical setting, if, when 09:59:52
17 you increase the light -- I'm sorry, the 09:59:56
18 pulse repetition rate, which means you're 10:00:01
19 delivering more photons, if the noise level 10:00:04
20 went up proportional to the number of photons 10:00:09
21 that you increased with the pulse repetition 10:00:13
22 rate, you would end up getting the same 10:00:15

1 signal-to-noise ratio. 10:00:17
2 BY MR. DAVIS: 10:00:18
3 Q. Does whether a signal-to-noise ratio increases 10:00:24
4 or decreases depend on whether the amount of 10:00:30
5 noise increases or decreases? 10:00:33
6 MR. CHRISTOPHER: Objection. Form 10:00:38
7 and scope. 10:00:39
8 A. Well, they're related, obviously. I mean, 10:00:43
9 signal-to-noise ratio is signal divided by 10:00:48
10 noise. So to -- as a particular example, if 10:00:51
11 you assume the signal were kept constant, 10:00:55
12 then increasing the noise would decrease the 10:00:59
13 signal-to-noise ratio proportionately. 10:01:02
14 I'm not sure I'm answering your 10:01:05
15 question, again, correctly. 10:01:06
16 BY MR. DAVIS: 10:01:08
17 Q. To know whether a signal-to-noise ratio 10:01:08
18 increased, do you need to know whether the 10:01:13
19 noise increased or decreased? 10:01:16
20 MR. CHRISTOPHER: Objection. Form 10:01:19
21 and scope. 10:01:20
22 A. Let me just repeat the question to make sure 10:01:24

1 I understood it. I think you're asking 10:01:27
2 that -- I'm sorry, could you repeat your 10:01:31
3 question? I'm not sure I followed it. 10:01:34
4 Sorry. 10:01:35
5 BY MR. DAVIS: 10:01:36
6 Q. To know whether a signal-to-noise ratio 10:01:36
7 increased, do you need to know whether the 10:01:38
8 noise increased or decreased? 10:01:42
9 MR. CHRISTOPHER: Same objections. 10:01:47
10 A. I -- so let me just see if I can repeat that 10:01:48
11 question. So if I measure the 10:02:04
12 signal-to-noise ratio, I get a number, let's 10:02:06
13 say. I don't necessarily know if that number 10:02:10
14 changed because the signal changed or the 10:02:13
15 noise changed. 10:02:15
16 And so without additional 10:02:17
17 information from simply knowing that the 10:02:18
18 signal-to-noise ratio changed, I can't -- 10:02:21
19 because there's two parameters, basically, 10:02:24
20 signal and noise. 10:02:26
21 So if you tell me all I'm going to 10:02:30
22 give you information about signal-to-noise 10:02:31

1 ratio, I can't determine definitively whether 10:02:35
2 it was the signal that changed or the noise 10:02:40
3 that changed. 10:02:43
4 Is that -- did that -- I'm not sure, 10:02:45
5 again, if I'm answering your question. 10:02:48
6 BY MR. DAVIS: 10:02:49
7 Q. To know whether a signal-to-noise ratio 10:03:03
8 increases, do you need to know whether the -- 10:03:05
9 both the signal changed and the noise changed? 10:03:09
10 MR. CHRISTOPHER: Objection. Form 10:03:13
11 and outside the scope. 10:03:16
12 A. Again, in your hypothetical question, if all 10:03:18
13 I'm given is that the signal-to-noise ratio 10:03:25
14 changed, only thing I can say for sure is 10:03:29
15 either the signal or the noise or both 10:03:37
16 changed, but I can't determine which changed 10:03:39
17 just simply from giving the output of the 10:03:43
18 signal-to-noise ratio, if that makes sense. 10:03:46
19 Again, there's two variables, and so 10:03:48
20 I can't sort that -- I can simply say the 10:03:50
21 ratio changed, but I can't work back to say 10:03:53
22 which of those changed without further 10:03:56

1 information. 10:03:58
2 BY MR. DAVIS: 10:03:58
3 Q. So there are two variables in a 10:03:59
4 signal-to-noise ratio, signal and noise. 10:04:02
5 Correct? 10:04:04
6 A. Yes, that's correct. 10:04:06
7 Q. If you know that signal increases, that's not 10:04:08
8 enough information to know whether the 10:04:14
9 signal-to-noise ratio increases; is that 10:04:16
10 correct? 10:04:18
11 MR. CHRISTOPHER: Objection. Form 10:04:20
12 and scope. 10:04:20
13 A. I believe that's a fair statement because, as 10:04:22
14 an example, if the noise level either went up 10:04:27
15 proportionally or faster than the signal 10:04:31
16 level went up, the signal-to-noise ratio 10:04:33
17 would not necessarily increase. 10:04:36
18 BY MR. DAVIS: 10:04:39
19 Q. And if you know that noise increases, that's 10:04:40
20 not enough information to know whether the 10:04:42
21 signal-to-noise ratio increases; is that 10:04:44
22 correct? 10:04:46

1 MR. CHRISTOPHER: Same objections. 10:04:46
2 A. Again, unless you give me further information 10:04:50
3 about the signal I cannot uniquely define 10:04:53
4 whether or not the signal-to-noise ratio 10:04:57
5 would change or how the signal-to-noise ratio 10:04:59
6 would change with a change in noise level. 10:05:02
7 BY MR. DAVIS: 10:05:05
8 Q. Prior to your patents, was it known to 10:05:05
9 increase pulse rate in a wearable device to 10:05:10
10 improve signal-to-noise ratio? 10:05:16
11 MR. CHRISTOPHER: Objection. Form 10:05:18
12 and scope. 10:05:18
13 A. I do not know whether in a wearable device it 10:05:22
14 was known to change pulse repetition rate to 10:05:27
15 change signal-to-noise ratio. 10:05:32
16 BY MR. DAVIS: 10:05:34
17 Q. Prior to your patents, in the field of 10:05:37
18 spectroscopy, was it known to increase pulse 10:05:42
19 rate to improve signal-to-noise ratio? 10:05:46
20 MR. CHRISTOPHER: Same objections. 10:05:51
21 A. Again, I'm not certain because I don't know 10:05:53
22 of anyone who did that. Usually these lasers 10:06:02

1 don't have adjustable pulse repetition rate 10:06:05
2 that you use in spectroscopy. So, actually, 10:06:10
3 I don't know the answer to that question. 10:06:13
4 BY MR. DAVIS: 10:06:17
5 Q. If a user turns up the pulse rate of the light 10:06:27
6 on a wearable device, would that improve the 10:06:32
7 signal-to-noise ratio? 10:06:35
8 MR. CHRISTOPHER: Objection. Form 10:06:37
9 and outside the scope. 10:06:38
10 A. Well, again, for starters, again, I don't 10:06:43
11 know of any wearables or -- wearable device 10:06:45
12 where the user has a knob they can adjust the 10:06:52
13 pulse repetition rate. But, again, in 10:06:56
14 general, it would improve the signal-to-noise 10:06:58
15 ratio, but it's not guaranteed to. 10:07:01
16 BY MR. DAVIS: 10:07:21
17 Q. In a laboratory setting, how would you 10:07:22
18 determine whether increasing pulse rate 10:07:28
19 improved the signal-to-noise ratio in a 10:07:30
20 wearable device? 10:07:31
21 MR. CHRISTOPHER: Same objections. 10:07:32
22 A. Again, in doing a Gedankenexperiment in the 10:07:43

1 laboratory settings, first, I would have to 10:07:47
2 have a light source that I can adjust the 10:07:49
3 repetition -- pulse repetition rate on. 10:07:51
4 There would be a pulse light source that I 10:07:55
5 can change the repetition rate on. 10:07:57
6 Again, I would have to have a 10:08:00
7 detector, and, again, perhaps a sample under 10:08:02
8 test. But we would look at -- first 10:08:07
9 determine the noise level by turning the 10:08:17
10 light source off and assume that all the 10:08:19
11 other conditions stay fixed, i.e., the room, 10:08:23
12 lights, temperature, et cetera, all being 10:08:26
13 fixed, we measure the noise level. 10:08:28
14 And then we turn on the light source 10:08:30
15 and measure a signal-to-noise ratio at a 10:08:36
16 given pulse repetition rate, and then we 10:08:41
17 change the pulse repetition rate and plot the 10:08:42
18 signal-to-noise ratio versus the pulse 10:08:45
19 repetition rate to see whether it's changing. 10:08:48
20 I don't know if that makes sense. 10:08:52
21 BY MR. DAVIS: 10:08:53
22 Q. If you were examining -- pardon me. 10:08:53

1 If you were examining a device, how 10:08:54
2 would you determine whether -- strike that. 10:09:01
3 If you were examining a wearable 10:09:04
4 device, how would you determine whether it 10:09:05
5 increases pulse rate to improve the 10:09:09
6 signal-to-noise ratio? 10:09:13
7 MR. CHRISTOPHER: Objection. Form. 10:09:15
8 Outside of scope of the declaration. 10:09:17
9 A. So let me just make sure I understand the 10:09:23
10 question, if I might. You're saying that if 10:09:25
11 I had a wearable device in a laboratory 10:09:27
12 setting, how could I see if the pulse 10:09:30
13 repetition rate's been changed? Is that what 10:09:34
14 you're asking? I'm sorry. 10:09:37
15 BY MR. DAVIS: 10:09:40
16 Q. I'm asking, if you were examining a wearable 10:09:40
17 device, how would you determine whether it 10:09:44
18 increases pulse rate to improve the 10:09:45
19 signal-to-noise ratio? 10:09:48
20 MR. CHRISTOPHER: Objection. Form. 10:09:49
21 Outside the scope. 10:09:50
22 A. Again, I would have to think more about this. 10:09:59

1 I can think of one example, but, again, I'm 10:10:02
2 sure there are many more ways of doing it. 10:10:04
3 BY MR. DAVIS: 10:10:16
4 Q. So if you were examining a wearable device, 10:10:16
5 how would you determine whether it increases 10:10:18
6 pulse rate to improve signal-to-noise ratio? 10:10:20
7 MR. CHRISTOPHER: Objection. Form. 10:10:23
8 Outside the scope. 10:10:24
9 A. Again, I'll give you one example of -- just 10:10:26
10 off the top of the head how I might do it, 10:10:30
11 but, again, that's something I'd have to 10:10:33
12 think a lot more about to really get a 10:10:34
13 definitive answer. 10:10:37
14 But as an example -- and just as an 10:10:37
15 example -- let's say I'm wearing a watch. 10:10:39
16 And to be more specific, let's say that it's 10:10:43
17 emitting pulsed green light; in other words, 10:10:46
18 a visible light that I can see either with my 10:10:51
19 eyes or a detector. 10:10:53
20 So in the wearable device, if I 10:10:55
21 slowly moved my wearable further away from 10:11:01
22 the skin, i.e., I'm getting less reflected 10:11:04

1 light from the skin, therefore weaker signal, 10:11:07
2 if I can see the pulsing of the green light, 10:11:12
3 if I can see whether that pulsing increases 10:11:14
4 more or not, that might be one way in which I 10:11:16
5 can see whether, in the laboratory setting, 10:11:20
6 that wearable device is changing the pulse 10:11:23
7 repetition rate to improve signal-to-noise 10:11:28
8 ratio. 10:11:32
9 So in that example -- again, that's 10:11:34
10 just merely an example. And, again, just off 10:11:36
11 the top of my head, as I'm moving that watch 10:11:39
12 or that wearable further from the skin, I'm 10:11:43
13 reducing the signal-to-noise ratio because 10:11:46
14 the amount of reflected light coming back 10:11:49
15 into the detector is reducing. 10:11:51
16 And then if I can -- if I can see 10:11:53
17 the blinking green light, if I can see 10:11:55
18 whether that rate of blinking is increasing, 10:11:57
19 that would say that that device was 10:12:02
20 increasing pulse repetition rate to improve 10:12:04
21 signal-to-noise ratio. 10:12:10
22 But that's, again, just a 10:12:11

1 Gedankenexperiment off the top of head. I'm 10:12:13
2 sure there's -- given enough time, I could 10:12:16
3 think about it more and come up with maybe a 10:12:18
4 better way to characterize that in a 10:12:20
5 laboratory setting. 10:12:21
6 BY MR. DAVIS: 10:12:24
7 Q. In a wearable device, is the light intensity 10:12:24
8 correlated to the signal? 10:12:33
9 MR. CHRISTOPHER: Objection. Form 10:12:35
10 and scope. 10:12:41
11 A. I guess you have to be more specific. Light 10:12:41
12 intensity of what? 10:12:43
13 BY MR. DAVIS: 10:12:44
14 Q. Well, we've been talking about increasing 10:12:45
15 light intensity in a wearable device. 10:12:47
16 Correct? 10:12:49
17 A. Yes, but, again, to be specific, are you 10:12:55
18 talking about the light intensity of the 10:12:56
19 light source on the wearable device -- 10:12:58
20 Q. Yes. 10:13:00
21 A. -- as opposed to the room light or something 10:13:01
22 else? 10:13:03

1 Q. Yes. So does increasing -- strike that. 10:13:03
2 Does the light intensity of the light 10:13:08
3 source in a wearable device correspond to the 10:13:15
4 signal in a signal-to-noise ratio? 10:13:20
5 MR. CHRISTOPHER: Objection. Form. 10:13:25
6 Outside the scope. 10:13:25
7 A. Well, again, I don't know I can answer that 10:13:32
8 question because you have to tell me what 10:13:35
9 your signal -- in other words, 10:13:40
10 signal-to-noise ratio is related to some 10:13:43
11 signal, so you have to explain what that 10:13:44
12 signal is before I can answer that question. 10:13:46
13 BY MR. DAVIS: 10:13:49
14 Q. Does increasing light intensity increase both 10:13:50
15 signal and noise in a signal-to-noise ratio? 10:13:53
16 MR. CHRISTOPHER: Same objections. 10:13:56
17 A. Again, signal-to-noise ratio of what, I 10:14:01
18 guess? As I think more about this, you know, 10:14:06
19 I've got to know what I'm talking about the 10:14:09
20 signal-to-noise ratio of. 10:14:11
21 BY MR. DAVIS: 10:14:13
22 Q. In a wearable device, does increasing the 10:14:13

1 light intensity of the light source increase 10:14:17
2 both the signal and the noise in a 10:14:19
3 signal-to-noise ratio? 10:14:22
4 MR. CHRISTOPHER: Objection. Form. 10:14:23
5 Outside the scope. 10:14:25
6 A. Again, signal of what, I guess, is I keep 10:14:28
7 coming back to. Signal of what? What are 10:14:32
8 you -- there has to be something that you're 10:14:34
9 tying the signal-to-noise ratio to. 10:14:36
10 BY MR. DAVIS: 10:15:02
11 Q. You're familiar with the concept of increasing 10:15:03
12 light intensity to increase signal-to-noise 10:15:05
13 ratio in a wearable device. Correct? 10:15:08
14 A. Well, again, I want to be -- I want to make 10:15:14
15 sure I'm answering your question correctly. 10:15:19
16 Are you talking about the signal-to-noise 10:15:21
17 ratio of, for example, a heart rate 10:15:27
18 measurement or something? I mean, it has -- 10:15:29
19 signal-to-noise ratio has to be of something. 10:15:31
20 You have to tell me what you're measuring. 10:15:33
21 Does that make sense? 10:15:36
22 Q. Are you able to answer my question without it 10:15:38

1 being tied to something specific? 10:15:40
2 MR. CHRISTOPHER: Objection. Form. 10:15:47
3 A. Well, if I don't know what the signal is and 10:15:47
4 I don't know what the noise is, I don't know 10:15:50
5 what the signal-to-noise ratio relates to, 10:15:51
6 so -- it has to be tied to something, I 10:15:53
7 think. 10:15:57
8 I mean, give you an example. If you 10:16:00
9 just simply turn on the room lights, increase 10:16:02
10 the light, you know, of your room lights, 10:16:04
11 does that mean improved signal-to-noise 10:16:07
12 ratio? Well, again, tell me what your 10:16:13
13 measure -- what your -- signal-to-noise ratio 10:16:15
14 of what? 10:16:16
15 BY MR. DAVIS: 10:16:25
16 Q. So the four patents at issue in these IPRs, do 10:16:26
17 you discuss in them the concept of increasing 10:16:29
18 light intensity to increase the 10:16:32
19 signal-to-noise ratio? 10:16:35
20 A. Yes, we do, but, again, we -- 10:16:45
21 Q. In that sense -- 10:16:46
22 A. Sorry. 10:16:47

1 Q. Apologize. I didn't realize you were not 10:16:49
2 finished. Let me ask the question and you can 10:16:51
3 answer. 10:16:55
4 In that context of the four patents 10:16:56
5 that are at issue in these IPRs, when you 10:17:01
6 increase light intensity, does that increase 10:17:07
7 the signal or the noise? 10:17:11
8 MR. CHRISTOPHER: Objection. Form. 10:17:15
9 A. Could you -- could we look at one particular 10:17:26
10 claim or something so we could better 10:17:28
11 understand your question, or -- you're asking 10:17:31
12 a very broad question. 10:17:33
13 BY MR. DAVIS: 10:17:36
14 Q. I'm asking about the concepts in your patents. 10:17:36
15 So with respect to this concept of increasing 10:17:42
16 light intensity, when you increase light 10:17:45
17 intensity, does that increase the signal or 10:17:48
18 the noise or both? 10:17:53
19 MR. CHRISTOPHER: Objection. Form. 10:17:56
20 A. Again, we're talking about tying the 10:18:01
21 signal-to-noise ratio, let's say, to a 10:18:09
22 physiological parameter measurement or some 10:18:14

1 sort of output from a processor or detector. 10:18:17
2 And in the context of the patents, in 10:18:24
3 general, we're assuming that the noise -- 10:18:29
4 again, in general, we're assuming the noise 10:18:38
5 is from the background, whether it be room 10:18:44
6 light, sunlight, whatever the environment is. 10:18:47
7 And so in the context of what we're 10:18:49
8 thinking about in the patents, we're thinking 10:18:53
9 about, with that background being more or 10:18:55
10 less constant by increasing the light 10:18:58
11 intensity, I'm increasing the signal-to-noise 10:19:00
12 ratio of that physiological parameter. 10:19:05
13 I'm not sure if I'm answering your 10:19:07
14 question. Is that what you're asking? 10:19:08
15 BY MR. DAVIS: 10:19:12
16 Q. So in the context of your patents, when you 10:19:12
17 increase light intensity, are you saying that 10:19:15
18 that's increasing the signal in a 10:19:18
19 signal-to-noise ratio? 10:19:21
20 A. Say that again, I'm sorry. 10:19:26
21 Q. In the context of your patents, when you 10:19:27
22 increase light intensity, are you saying that 10:19:30

1 that's increasing the signal in a 10:19:33
2 signal-to-noise ratio? 10:19:36
3 A. Yes, but we have to again tie the 10:19:46
4 signal-to-noise ratio to a parameter that 10:19:48
5 we're saying. I don't know -- I think -- 10:19:52
6 again, suggestion, if we could look at one 10:19:54
7 claim, let's say, of the '455 patent or 10:19:58
8 something, and I can maybe better answer your 10:20:00
9 question in terms of signal-to-noise ratio. 10:20:02
10 Q. So in the context of your patents, when you 10:20:05
11 increase light intensity, is -- does that mean 10:20:07
12 that the signal is being increased? 10:20:14
13 MR. CHRISTOPHER: Objection. Form. 10:20:17
14 A. So, again, I want to -- I want to try to 10:20:19
15 answer the question as best I can. 10:20:26
16 So, first, I have to define an 10:20:27
17 output signal of some sort, so that has to 10:20:29
18 first be defined. In other words, I have to 10:20:33
19 define what is it that I'm talking the 10:20:34
20 signal-to-noise ratio about. 10:20:38
21 And in the context of our patents, 10:20:42
22 what we're envisioning in general is that the 10:20:46

1 background is coming -- the noise, if you 10:20:51
2 like, is coming from the environment, you 10:20:53
3 know, whether that be sunlight, room lights, 10:20:55
4 you know, whatever else, noise that may be 10:20:59
5 around. 10:21:05
6 And then when I'm increasing the 10:21:06
7 light intensity of the, for example, 10:21:11
8 light-emitting diodes that might be on that 10:21:13
9 wearable device -- again, a specific 10:21:16
10 example -- as long as I've defined what that 10:21:18
11 output signal is, we're saying that when I 10:21:20
12 increase that light intensity of that LED, 10:21:22
13 and given that the environment hasn't 10:21:26
14 changed, I have now improved my 10:21:29
15 signal-to-noise ratio. 10:21:30
16 But that's again -- I'm giving you 10:21:31
17 one example and -- if we can point to, for 10:21:33
18 example, one of the claims, I can tell you 10:21:34
19 how we're doing that or how we're defining 10:21:38
20 signal-to -- how we're defining signal, how 10:21:41
21 we're defining signal-to-noise ratio, and 10:21:43
22 then how we're changing the light source. 10:21:44

1 BY MR. DAVIS: 10:21:49
2 Q. In the context of your patents, does 10:21:50
3 increasing the light intensity increase the 10:21:51
4 noise in a signal-to-noise ratio? 10:21:54
5 MR. CHRISTOPHER: Objection to form. 10:21:57
6 A. Well, I cannot answer that question in the 10:22:00
7 abstract, I guess, because to answer that I 10:22:11
8 would have to know more about the light 10:22:14
9 source. But, again, if I -- if I make the 10:22:16
10 assumption -- which is not, again, written in 10:22:19
11 the claims or anything like that. 10:22:24
12 But if I assume that the environment 10:22:25
13 is the source of the noise and the light 10:22:27
14 source does not increase and the light source 10:22:31
15 does not introduce more noise, then changing 10:22:37
16 light intensity doesn't change the noise -- 10:22:41
17 I'm not sure if I'm answering your 10:22:43
18 question. Maybe you could repeat it again. 10:22:44
19 BY MR. DAVIS: 10:22:50
20 Q. In the context of your patents, does 10:22:50
21 increasing the light intensity increase the 10:22:51
22 noise in a signal-to-noise ratio? 10:22:55

1 MR. CHRISTOPHER: Objection to form. 10:22:57
2 A. Again, that -- I'd have to know more about 10:23:02
3 the light source to be able to answer that 10:23:07
4 question. 10:23:09
5 BY MR. DAVIS: 10:23:09
6 Q. In the context of your patents, do you assume 10:23:10
7 that the noise in a signal-to-noise ratio 10:23:14
8 refers to the noise from the environment? 10:23:21
9 MR. CHRISTOPHER: Objection to form 10:23:27
10 and scope. 10:23:27
11 A. In the context of the patents, certainly one 10:23:32
12 of the sources of noise is the environment, 10:23:34
13 but it may not be the only one, I guess. 10:23:37
14 BY MR. DAVIS: 10:23:41
15 Q. In the context of your patents, what are the 10:23:41
16 sources of noise in a signal-to-noise ratio? 10:23:44
17 MR. CHRISTOPHER: Objection to form 10:23:48
18 and scope. 10:23:48
19 A. Well, again, just off the top of my head, 10:23:53
20 certainly sources of noise can include in 10:23:55
21 the -- again, in the context of my patent, 10:24:01
22 sunlight or ambient light. It can include 10:24:03

1 motion, for example. It can include 10:24:10
2 interference from other things such as the 10:24:15
3 skin or even other maybe -- depending on what 10:24:18
4 you're trying to measure, blood constituents 10:24:25
5 or something else that may be interfering 10:24:28
6 with your signal, so... 10:24:30
7 BY MR. DAVIS: 10:24:32
8 Q. Can the light source of a wearable device -- 10:24:32
9 A. I'm sorry? 10:24:35
10 Q. -- be a contributor to the noise in a 10:24:35
11 signal-to-noise ratio? 10:24:40
12 MR. CHRISTOPHER: Objection to form 10:24:41
13 and scope. 10:24:42
14 A. So, again, talking at a high level, I guess 10:24:48
15 maybe from a physics perspective -- and I 10:24:56
16 apologize. Since I teach optics and 10:24:58
17 photonics, I sort of have to describe it in 10:25:00
18 that context. 10:25:04
19 So every light source has noise 10:25:05
20 associated with it. Even in the best of 10:25:12
21 light sources -- it's called shot noise. 10:25:15
22 So every light source has noise 10:25:18

1 associated with it, but also there's noise 10:25:20
2 associated with the detector, there's noise 10:25:23
3 associated with the receiver behind it. 10:25:26
4 And so, again, you have to -- to 10:25:28
5 answer your question, every part of the 10:25:31
6 system introduces noise, but, you know -- so, 10:25:35
7 yeah, even in -- even in the best of best 10:25:40
8 light source, best of laser that you can buy 10:25:46
9 out there, there will be noise. 10:25:49
10 BY MR. DAVIS: 10:25:50
11 Q. In the context of your patents, does the pulse 10:25:50
12 rate of a light source on a wearable device 10:26:03
13 contribute to the signal in a signal-to-noise 10:26:08
14 ratio? 10:26:13
15 MR. CHRISTOPHER: Objection to form 10:26:13
16 and scope. 10:26:14
17 A. Again, if I understand your question 10:26:26
18 correctly, let's -- let me -- to answer that 10:26:28
19 question, let me make one assumption. Let me 10:26:30
20 assume that the light source is able to 10:26:33
21 maintain the same height or pulse intensity, 10:26:35
22 light intensity, as it changes repetition 10:26:40

1 rate. Again, that's not always true, but 10:26:44
2 let's assume that for a moment. 10:26:47
3 If we assume that, then when I 10:26:48
4 increase the pulse repetition rate, I would 10:26:51
5 be increasing the number of photons going to 10:26:56
6 the detector and, in general, that would then 10:27:00
7 improve the signal-to-noise ratio. 10:27:04
8 So, again, in general, increasing 10:27:07
9 the pulse repetition rate improves the 10:27:10
10 signal-to-noise ratio. And as we talked 10:27:15
11 about, you know, there can be extenuating 10:27:16
12 circumstances; hopefully you don't design to 10:27:19
13 those, but, you know, either, A, detector got 10:27:21
14 saturated when too many photons hit it; or, 10:27:24
15 B, the light source intensity decreased when 10:27:27
16 you increased the repetition rate because 10:27:29
17 there's only so much energy it can deliver. 10:27:31
18 So, again there could be exceptions 10:27:33
19 based on those two examples, but other than 10:27:40
20 that, in general, as long as you're operating 10:27:42
21 in that linear regime for the detector and 10:27:44
22 your light source can deliver more or less 10:27:46

1 constant intensity as you increase the pulse 10:27:49
2 repetition rate, in the context of our 10:27:54
3 patents, certainly increasing the pulse 10:27:55
4 repetition rate would increase 10:27:58
5 signal-to-noise ratio. 10:27:59
6 MR. CHRISTOPHER: And Counsel -- 10:28:00
7 BY MR. DAVIS: 10:28:01
8 Q. In the context of a wearable device, every 10:28:02
9 component would introduce noise to a 10:28:04
10 signal-to-noise ratio; is that correct? 10:28:09
11 MR. CHRISTOPHER: Objection to form 10:28:10
12 and scope. 10:28:12
13 And when we get a moment -- we've 10:28:12
14 gone a little over an hour, if we could get to 10:28:15
15 a breaking point here. 10:28:18
16 THE WITNESS: I'd like to think of it 10:28:21
17 as a point for a break rather than a breaking 10:28:22
18 point, but anyway... 10:28:24
19 BY MR. DAVIS: 10:28:26
20 Q. Why don't I reask the question. Just so we 10:28:27
21 have -- 10:28:27
22 A. Yeah. 10:28:27

1 Q. -- a live question. Sorry. 10:28:29
2 In the context of a wearable device, 10:28:30
3 every component would introduce noise to a 10:28:31
4 signal-to-noise ratio. Correct? 10:28:36
5 MR. CHRISTOPHER: Same objections. 10:28:37
6 A. Yes, it's true that -- again, when you say 10:28:40
7 "every component," let me be more specific. 10:28:42
8 So if I'm, for example, trying to do heart 10:28:46
9 rate measurement or something then every 10:28:51
10 component involved in that, such as the light 10:28:53
11 source, the detector, the electronics behind 10:28:55
12 that, and the receiver, each of those would 10:29:00
13 introduce some sort of noise, yes, that's 10:29:04
14 correct. 10:29:06
15 BY MR. DAVIS: 10:29:06
16 Q. Thank you. 10:29:08
17 MR. DAVIS: We can go off the record. 10:29:08
18 (Off the record at 10:29 a.m.) 10:29:09
19 (Back on the record at 10:37 a.m.) 10:37:47
20 BY MR. DAVIS: 10:37:54
21 Q. Does synchronizing light emitters and 10:37:55
22 detectors in a wearable device always improve 10:37:58

1 the signal-to-noise ratio? 10:38:01
2 MR. CHRISTOPHER: Objection to form 10:38:02
3 and scope. 10:38:02
4 A. In general, synchronizing the detectors to 10:38:08
5 the light source improves signal-to-noise 10:38:12
6 ratio. 10:38:29
7 BY MR. DAVIS: 10:38:29
8 Q. Does it always improve the signal-to-noise 10:38:30
9 ratio? 10:38:32
10 MR. CHRISTOPHER: Same objections. 10:38:32
11 A. I'm trying to think of an instance where it 10:38:43
12 wouldn't. Again, in general, it -- 10:38:48
13 synchronizing -- in general, in synchronizing 10:38:52
14 the detector to the light source improves 10:38:55
15 signal-to-noise ratio because you're not 10:38:57
16 collecting noise during the time the light 10:39:01
17 source is off. That's the general reason. 10:39:04
18 I'm sure there might be some weird 10:39:10
19 circumstances where synchronizing doesn't 10:39:12
20 improve the signal-to-noise ratio, but off 10:39:16
21 the top of the head -- off the top of my 10:39:17
22 head, sitting here, I can't think of an 10:39:18

1 instance of that, but I'm sure there must be. 10:39:25
2 BY MR. DAVIS: 10:39:27
3 Q. When you say "synchronizing light sources and 10:39:28
4 detectors in a wearable device," what do you 10:39:35
5 mean by "synchronizing"? 10:39:37
6 MR. CHRISTOPHER: Same objections. 10:39:43
7 A. As an example, the detector measures when the 10:39:44
8 light source is on; in other words, when I 10:39:49
9 turn on the light source, I also look at the 10:39:51
10 light received at the detector during that 10:39:59
11 period of time when the light source is on. 10:40:01
12 So understanding -- you know, 10:40:03
13 unless -- and, again, most wearable devices, 10:40:06
14 as an example, don't have this unless you 10:40:08
15 have a block, a shutter or something in front 10:40:10
16 of the detector. The detector is always 10:40:13
17 looking. It's always measuring. But by 10:40:15
18 synchronizing, what you're saying is I'm only 10:40:19
19 going to look at the output of the detector 10:40:22
20 at the time that the light source is on. 10:40:24
21 So that's the context. Is that -- 10:40:30
22 am I answering your question? I'm sorry. I 10:40:32

1 think you asked, if I understand you 10:40:34
2 correctly, what do we mean by synchronizing 10:40:35
3 in the context of my patent. Is that a 10:40:38
4 correct statement? 10:40:42
5 BY MR. DAVIS: 10:40:43
6 Q. Let me reask the question. 10:40:43
7 A. I'm sorry. Please. 10:40:45
8 Q. In the context of your patents -- 10:40:46
9 A. Sorry, I interrupted you. 10:40:49
10 Q. No problem. 10:40:50
11 In the context of your patents, what 10:40:51
12 does it mean to synchronize light emitters and 10:40:57
13 detectors? 10:41:02
14 MR. CHRISTOPHER: Objection to form. 10:41:07
15 A. In the context of my patent, by synchronizing 10:41:08
16 the light source and the detector, what we 10:41:12
17 mean is that, when the light source is turned 10:41:14
18 on, the detector signal is measured. 10:41:16
19 BY MR. DAVIS: 10:41:24
20 Q. Does synchronizing light sources and detectors 10:41:25
21 in a wearable device contribute to the signal 10:41:33
22 or the noise in a signal-to-noise ratio? 10:41:37

1 MR. CHRISTOPHER: Objection. Form. 10:41:45
2 A. By synchronizing the light source and a 10:41:55
3 detector in a wearable device, I am reducing 10:41:58
4 what would otherwise be the noise level that 10:42:06
5 would be in the signal-to-noise ratio because 10:42:08
6 I'm not measuring or taking into that 10:42:11
7 measurement the background light noise that 10:42:14
8 would be occurring when the light source is 10:42:23
9 off. 10:42:24
10 BY MR. DAVIS: 10:42:25
11 Q. Does increasing light intensity in a wearable 10:42:25
12 device contribute to the signal or the noise 10:42:28
13 in a signal-to-noise ratio? 10:42:29
14 MR. CHRISTOPHER: Objection. Form. 10:42:34
15 A. Again, being specific to the signal-to-noise 10:42:39
16 ratio, let's say, of a measurement by the 10:42:42
17 wearable device, by increasing the light 10:42:45
18 intensity of the light source such as, for 10:42:50
19 example, an LED, that being the light source, 10:42:52
20 in general, it increases the signal of the 10:42:58
21 signal-to-noise ratio in that -- in general. 10:43:01
22 BY MR. DAVIS: 10:43:05

1 Q. Does increasing pulse rate in a wearable 10:43:05
2 device contribute to the signal or the noise 10:43:10
3 in a signal-to-noise ratio? 10:43:14
4 MR. CHRISTOPHER: Objection to form. 10:43:15
5 A. Again, in general, by increasing the pulse 10:43:20
6 repetition rate of the light source I'm 10:43:28
7 increasing the signal level at the receiver 10:43:31
8 of the signal-to-noise ratio because I'm 10:43:37
9 increasing the number of photons that are 10:43:39
10 available for the measurement. 10:43:41
11 BY MR. DAVIS: 10:43:47
12 Q. And prior to your patents, was it known in the 10:43:47
13 field to synchronize light emitters and 10:43:49
14 detectors in wearable devices? 10:43:53
15 MR. CHRISTOPHER: Objection to form 10:43:55
16 and scope. 10:43:56
17 A. I'm sorry. Again, you referred to two 10:44:01
18 things, "field" and "wearable." You mean, in 10:44:04
19 the field of wearables? Just to be certain I 10:44:06
20 understand your question. 10:44:09
21 BY MR. DAVIS: 10:44:09
22 Q. Sure. Why don't -- I'll reask the question. 10:44:10

1 Prior to your patents, was it known 10:44:12
2 to synchronize light emitters and detectors in 10:44:13
3 a wearable device? 10:44:16
4 MR. CHRISTOPHER: Same objections. 10:44:17
5 A. I don't know the answer to that question. 10:44:24
6 BY MR. DAVIS: 10:44:25
7 Q. Prior to your patents, was it known to 10:44:25
8 synchronize light emitters and detectors in a 10:44:33
9 wearable device to improve signal-to-noise 10:44:38
10 ratio? 10:44:40
11 MR. CHRISTOPHER: Objection to form 10:44:40
12 and scope. 10:44:41
13 A. Again, I don't -- I don't know the answer to 10:44:45
14 that question. 10:44:47
15 BY MR. DAVIS: 10:44:49
16 Q. If you were analyzing a device -- strike that. 10:44:59
17 If you were analyzing a wearable 10:45:01
18 device, how would you tell if synchronizing 10:45:03
19 the light sources and detectors would improve 10:45:07
20 the signal-to-noise ratio? 10:45:11
21 MR. CHRISTOPHER: Objection. Outside 10:45:12
22 the scope. 10:45:21

1 A. Well, again, as -- if I'm just -- as a user 10:45:21
2 of the device, I certainly wouldn't be able 10:45:24
3 to do that. Again, I don't have control. I 10:45:26
4 don't have those knobs, let's say, on my 10:45:29
5 Apple Watch. But I could imagine how to do 10:45:31
6 it in a laboratory setting if I had access to 10:45:35
7 all the signals and all the material in 10:45:38
8 the -- all the things that are going on in 10:45:40
9 the watch. 10:45:43
10 BY MR. DAVIS: 10:45:43
11 Q. In a laboratory setting, how would you 10:45:43
12 determine whether synchronizing the light 10:45:45
13 sources and detectors in a wearable device 10:45:49
14 improved the signal-to-noise ratio? 10:45:52
15 MR. CHRISTOPHER: Objection. Outside 10:45:55
16 the scope. 10:46:01
17 A. Well, again, let me give you one example. 10:46:01
18 And, again, not -- and, again, this is just 10:46:03
19 off the top of my head. 10:46:04
20 So let me make the assumption that 10:46:05
21 the light source is pulsed, and I would do 10:46:07
22 two measurements, one where the detector is 10:46:17

1 always on. In other words, I don't follow 10:46:20
2 the light source, I don't synchronize the 10:46:23
3 light source, just let it stay on all the 10:46:26
4 time and look at what the resulting 10:46:28
5 signal-to-noise ratio is. 10:46:32
6 And then in the second instance, 10:46:33
7 synchronize the detector so it's only looking 10:46:35
8 when the light source is on, and look at the 10:46:37
9 signal-to-noise ratio for that. 10:46:39
10 And by comparing those two, I would 10:46:41
11 see whether synchronizing the light source 10:46:44
12 helped or improved the signal-to-noise ratio. 10:46:47
13 BY MR. DAVIS: 10:46:56
14 Q. To know whether a signal-to-noise ratio has 10:46:56
15 increased, do you need to know whether the 10:46:58
16 noise has increased? 10:47:01
17 MR. CHRISTOPHER: Objection to form. 10:47:09
18 Outside the scope. 10:47:11
19 A. As we said before, signal-to-noise ratio has 10:47:11
20 two variables, the signal and the noise. So 10:47:14
21 I -- I can't answer that question without 10:47:20
22 also knowing something about the signal. In 10:47:22

1 other words, if the noise -- you're -- if I 10:47:25
2 understood you correctly, you said if the 10:47:27
3 noise goes up, does the signal-to-noise ratio 10:47:29
4 change. And the question is whether the 10:47:32
5 signal changed proportionally or not. 10:47:34
6 So, again, there's two variables. 10:47:37
7 Without knowing both, I can't properly answer 10:47:39
8 that question. 10:47:42
9 BY MR. DAVIS: 10:47:43
10 Q. To know whether a signal-to-noise ratio has 10:47:43
11 increased, you would need to know whether the 10:47:46
12 noise and the signal have increased and by how 10:47:49
13 much? 10:47:52
14 MR. CHRISTOPHER: Objection to form. 10:47:53
15 It's outside of scope of the declaration. 10:47:54
16 A. Well, I guess I can answer that. If I know 10:48:07
17 how the signal has changed and I know how the 10:48:10
18 noise has changed, then I know how the ratio 10:48:13
19 has changed as well, if that's what you're 10:48:15
20 asking. In other words, if you give me more 10:48:16
21 pieces of information, I can take the ratio 10:48:18
22 and calculate the signal-to-noise ratio. 10:48:20

1 But, again, I think your question 10:48:21
2 earlier, if I understood you correctly, was 10:48:22
3 if you only tell me the noise changed, I 10:48:25
4 can't tell you how the signal-to-noise ratio 10:48:30
5 changed unless you tell me something about 10:48:31
6 the signal as well. 10:48:33
7 BY MR. DAVIS: 10:48:37
8 Q. I'm going to reask that then. 10:48:37
9 If you only know whether the noise 10:48:38
10 changed, you don't know whether the 10:48:40
11 signal-to-noise ratio has increased; is that 10:48:42
12 correct? 10:48:44
13 MR. CHRISTOPHER: Objection to form. 10:48:45
14 Outside the scope. 10:48:46
15 A. Unless you tell me something about the signal 10:48:52
16 level, I can't tell you definitively whether 10:48:56
17 the signal-to-noise ratio has increased or 10:49:01
18 decreased. If you told me the signal level 10:49:04
19 were fixed, and you tell me I increased the 10:49:08
20 noise level, then I would tell you, yes, for 10:49:13
21 the fixed signal level, the signal-to-noise 10:49:15
22 ratio will decrease when you increase the 10:49:18

1 noise level. 10:49:19
2 BY MR. DAVIS: 10:49:21
3 Q. If you only know whether the signal changed, 10:49:21
4 you don't know whether the signal-to-noise 10:49:24
5 ratio has increased; is that correct? 10:49:27
6 MR. CHRISTOPHER: Objection to form. 10:49:31
7 Outside the scope. 10:49:33
8 A. Again, if you tell me that I have only 10:49:33
9 increased the signal and tell me nothing 10:49:35
10 about the noise, I cannot definitively tell 10:49:38
11 you how the signal-to-noise ratio will have 10:49:41
12 changed. 10:49:47
13 BY MR. DAVIS: 10:49:47
14 Q. Does using change detection in a wearable 10:49:48
15 device always improve the signal-to-noise 10:49:51
16 ratio? 10:49:53
17 MR. CHRISTOPHER: Objection. Form. 10:49:59
18 Scope. 10:50:01
19 A. In general, using change detection -- and, 10:50:01
20 again, to be specific, when I talk about 10:50:04
21 change detection, I mean comparing when the 10:50:07
22 light is off versus when the light is on at 10:50:08

1 the detector. In general, using change 10:50:11
2 detection does improve the signal-to-noise 10:50:13
3 ratio of the physiological parameter; for 10:50:15
4 example, the signal that you're trying to 10:50:19
5 measure. 10:50:21
6 BY MR. DAVIS: 10:50:21
7 Q. Does using change detection in a wearable 10:50:22
8 device always improve the signal-to-noise 10:50:25
9 ratio? 10:50:26
10 MR. CHRISTOPHER: Objection. Form. 10:50:27
11 A. Again, in general, it does. I'm sure there 10:50:33
12 must be some esoteric case where it doesn't, 10:50:42
13 but in general -- I can't think off the top 10:50:46
14 of my head, but, in general, it is true the 10:50:48
15 change detection helps improve the 10:50:50
16 signal-to-noise ratio. 10:50:52
17 BY MR. DAVIS: 10:50:53
18 Q. Does change detection in a wearable device 10:50:54
19 contribute to the signal or the noise in a 10:51:00
20 signal-to-noise ratio? 10:51:03
21 MR. CHRISTOPHER: Objection. Form. 10:51:03
22 A. So by using change detection what we're 10:51:08

1 trying to do is subtract out the ambient 10:51:16
2 noise. In other words, the noise level 10:51:23
3 that's there when the light source is off. 10:51:25
4 And so that includes, for example, from the 10:51:27
5 environment, such as including ambient light. 10:51:29
6 It also might include from the detector and 10:51:33
7 the receiver noise, et cetera, of that 10:51:36
8 circuitry. 10:51:41
9 So by subtracting the light off time 10:51:41
10 from the light on -- or the light off signal 10:51:44
11 from the light on signal we're reducing the 10:51:48
12 noise level, and by that means increasing the 10:51:51
13 signal-to-noise ratio. 10:51:55
14 I guess -- I'm sorry. If I may go 10:51:57
15 back on your earlier question for one moment, 10:51:59
16 when you asked about does change detection 10:52:04
17 always help the signal-to-noise ratio -- 10:52:06
18 Q. Why don't -- why don't I ask the question and 10:52:10
19 we can -- 10:52:12
20 A. I'm sorry. I'm sorry. Okay, that's fine. 10:52:13
21 Q. Yeah. So stick with the question we were on. 10:52:14
22 A. Yes. 10:52:17

1 Q. Is it your testimony that change detection in 10:52:18
2 a wearable device impacts the noise but not 10:52:24
3 the signal in a signal-to-noise ratio? 10:52:28
4 MR. CHRISTOPHER: Objection. Form. 10:52:31
5 A. It's my testimony that by using change 10:52:32
6 detection, what you're trying to do is reduce 10:52:42
7 the noise contribution in the signal-to-noise 10:52:44
8 ratio by subtracting off the noise when the 10:52:48
9 light source is off. It's often called, for 10:52:53
10 example, dark current, that kind of noise. 10:52:55
11 BY MR. DAVIS: 10:52:58
12 Q. Does using change detection in a wearable 10:52:58
13 device always improve the signal-to-noise 10:53:01
14 ratio? 10:53:03
15 MR. CHRISTOPHER: Objection. Form. 10:53:04
16 A. In general -- and going back to your earlier 10:53:06
17 question which you just reasked, I believe, 10:53:14
18 in general, doing change detection improves 10:53:16
19 the signal-to-noise ratio. It doesn't 10:53:20
20 necessarily always have to. And I guess -- 10:53:24
21 as I said, I'll -- in general, it will. 10:53:28
22 The assumption is that the noise 10:53:31

1 level doesn't change between when the light 10:53:32
2 source is off and the light source is on from 10:53:36
3 the -- from the background. 10:53:39
4 BY MR. DAVIS: 10:53:43
5 Q. In your patents, are you assuming that the 10:53:43
6 noise level does not change when you're 10:53:48
7 talking about increasing the signal-to-noise 10:53:50
8 ratio? 10:53:53
9 MR. CHRISTOPHER: Objection. Form. 10:53:54
10 A. In the -- in the context of some of the 10:53:54
11 claims related to wearable devices, what we 10:54:06
12 are thinking or assuming is that the noise 10:54:12
13 level comes from the ambient setting which 10:54:18
14 might include the ambient light, might 10:54:29
15 include how you're wearing the device, might 10:54:31
16 include how much motion you're doing, 10:54:35
17 et cetera. 10:54:37
18 So -- I'm sorry, maybe repeat your 10:54:42
19 question. I'm not sure if I'm answering you 10:54:45
20 correctly. 10:54:47
21 BY MR. DAVIS: 10:54:47
22 Q. In your patents, are you assuming that the 10:54:48

1 noise level does not change when you're 10:54:53
2 talking about increasing the signal-to-noise 10:54:55
3 ratio? 10:54:58
4 MR. CHRISTOPHER: Objection. Form. 10:54:59
5 A. In the context of our patent, the claims 10:55:00
6 particularly, we're assuming that the noise 10:55:08
7 level is coming from, again, the ambient 10:55:12
8 setting, how it's being worn, et cetera. And 10:55:16
9 so the things we're doing, such as increasing 10:55:19
10 light intensity, by increasing pulse 10:55:24
11 repetition rate, change detection, 10:55:28
12 synchronization, all of these are helping to 10:55:31
13 improve the signal-to-noise ratio because the 10:55:37
14 noise isn't changing because the background 10:55:40
15 is the same. 10:55:43
16 Is that answering your question? 10:55:44
17 BY MR. DAVIS: 10:55:46
18 Q. What is change detection? 10:55:47
19 A. So if I were to consider that I -- let's say 10:55:50
20 I pulsed light, meaning on -- off light, on 10:55:53
21 light, off light, on light, change detection 10:55:58
22 would, for example, be considered the light 10:56:01

1 coming out of the receiver when the light -- 10:56:04
2 I'm sorry, the signal coming out of the 10:56:06
3 receiver when the light source is on, and 10:56:08
4 then taking the signal from the receiver when 10:56:11
5 the light source is off and comparing them, 10:56:16
6 for example, by subtracting them. 10:56:19
7 Q. Prior to your patents, was it known to use 10:56:44
8 change detection in wearable devices? 10:56:47
9 MR. CHRISTOPHER: Objection to form. 10:56:50
10 Scope. 10:56:51
11 A. I do not know that it was known. 10:56:52
12 BY MR. DAVIS: 10:56:59
13 Q. Prior to your patents, was it known to use 10:56:59
14 change detection in wearable devices to 10:57:02
15 improve signal-to-noise ratio? 10:57:05
16 MR. CHRISTOPHER: Same objections. 10:57:07
17 A. Again, I do not know that. 10:57:09
18 BY MR. DAVIS: 10:57:14
19 Q. In the field of optical sensing, was it known 10:57:14
20 to use change detection to improve 10:57:18
21 signal-to-noise ratio prior to your patents? 10:57:22
22 MR. CHRISTOPHER: Same objections. 10:57:24

1 A. As I said, optical sensing is a very broad 10:57:25
2 field. If we could be more specific, for 10:57:33
3 example, of optical reconnaissance, I can 10:57:37
4 answer that question. 10:57:42
5 BY MR. DAVIS: 10:57:42
6 Q. Just generally, in the field of optical 10:57:43
7 sensing, was it known prior to your patents to 10:57:45
8 use change detection to improve 10:57:47
9 signal-to-noise ratio? 10:57:50
10 MR. CHRISTOPHER: Objection to form 10:57:55
11 and scope. 10:57:56
12 A. Again, optical sensing is very broad. As we 10:57:56
13 said, optical sensing even can include my 10:57:59
14 looking at you on this Zoom screen. But 10:58:02
15 in -- what I know is that in the field of 10:58:10
16 optical reconnaissance, change detection was 10:58:14
17 known. 10:58:15
18 BY MR. DAVIS: 10:58:19
19 Q. What about in the broader field of optical 10:58:19
20 sensing? Was it known prior to your patents 10:58:22
21 to use change detection to improve 10:58:25
22 signal-to-noise ratio? 10:58:28

1 MR. CHRISTOPHER: Same objections. 10:58:33
2 A. Well, again, optical reconnaissance is one 10:58:33
3 area of optical sensing, so I'm not sure I 10:58:37
4 understand your question. 10:58:40
5 BY MR. DAVIS: 10:58:40
6 Q. You would agree that, in the field of optical 10:58:44
7 sensing, it was known prior to your patents to 10:58:51
8 use change detection to improve 10:58:54
9 signal-to-noise ratio? 10:58:56
10 MR. CHRISTOPHER: Objection. Form. 10:58:57
11 Scope. 10:58:59
12 A. Well, what I know -- again, from my knowledge 10:58:59
13 in the field of optical reconnaissance, it 10:59:05
14 was known to use change detection. Again, 10:59:07
15 "optical sensing" is very broad, and I don't 10:59:12
16 know where else it was used, but from what I 10:59:14
17 know, it's used in optical reconnaissance. 10:59:16
18 BY MR. DAVIS: 10:59:22
19 Q. And you'd consider optical reconnaissance to 10:59:22
20 be within the field of optical sensing? 10:59:25
21 A. It would be one branch of optical sensing, 10:59:26
22 broadly speaking. 10:59:29

1 Q. If you were looking at -- strike that. 10:59:31
2 In a laboratory setting, how would 10:59:34
3 you determine whether change detection was 10:59:38
4 being used to improve signal-to-noise ratio in 10:59:41
5 a wearable device? 10:59:44
6 MR. CHRISTOPHER: Objection. It's 10:59:47
7 outside the scope. 10:59:48
8 A. So, again, we're going into hypothetical 10:59:53
9 Gedankenexperiment. But if I had that 10:59:57
10 wearable device in my laboratory, I would 11:00:00
11 actually -- I guess I'd have to know 11:00:12
12 something about the algorithm of the 11:00:18
13 processing. In other words, I'd have to know 11:00:19
14 is that receiver looking at the light on time 11:00:24
15 and the light off time and subtracting those 11:00:29
16 or comparing them somehow. 11:00:31
17 Without knowing the algorithm -- I'm 11:00:34
18 sure there's probably a way to do an 11:00:45
19 experiment to see whether change detection is 11:00:47
20 being used, but certainly the easiest way to 11:00:50
21 determine whether the -- whether change 11:00:53
22 detection is being used is -- would be 11:00:54

1 knowing what the algorithm that the processor 11:00:56
2 is doing and whether it's comparing the light 11:00:58
3 on with the light off times. 11:01:02
4 BY MR. DAVIS: 11:01:04
5 Q. Does using -- does using spatially separated 11:01:04
6 detectors in a wearable device always improve 11:01:08
7 the signal-to-noise ratio? 11:01:10
8 MR. CHRISTOPHER: Objection to form. 11:01:12
9 A. In general, using spatially separated 11:01:23
10 detectors does -- will probably increase your 11:01:25
11 signal-to-noise ratio on a wearable device. 11:01:32
12 The idea is that, for example, when I, let's 11:01:39
13 say, wear a watch, I don't know whether the 11:01:41
14 light source -- I don't know -- I would like 11:01:45
15 to have a detector that's as close as 11:01:51
16 possible to light that's being reflected off 11:01:53
17 the blood. And so by having spatially 11:01:56
18 separated detectors, I might improve the 11:01:59
19 probability that I find signal that's 11:02:02
20 reflected off the blood. 11:02:05
21 BY MR. DAVIS: 11:02:07
22 Q. So is it your testimony that using spatially 11:02:16

1 separated detectors in a wearable device 11:02:18
2 always improves the signal-to-noise ratio? 11:02:20
3 MR. CHRISTOPHER: Objection to form. 11:02:23
4 A. No. It's my testimony that using spatially 11:02:25
5 separated detectors generally can improve the 11:02:30
6 signal-to-noise ratio. 11:02:35
7 BY MR. DAVIS: 11:02:38
8 Q. When does using spatially separated detectors 11:02:38
9 in a wearable device not improve the 11:02:41
10 signal-to-noise ratio? 11:02:43
11 MR. CHRISTOPHER: Object to form. 11:02:46
12 A. You know, again, if you -- I'll give you one 11:02:49
13 example, and, again, thinking off the top of 11:03:03
14 my head here. 11:03:05
15 So let's say I have two detectors 11:03:06
16 and one happened to be close to where the 11:03:10
17 blood is -- where the light is being 11:03:14
18 reflected off the blood, so I have a good, 11:03:17
19 what's called, photoplethysmography, or PPG, 11:03:19
20 signal. And let's say the other detector is 11:03:23
21 way off, there's no light being received, so 11:03:26
22 all I'm getting is the ambient effects. 11:03:28

1 So I have one detector that has a 11:03:30
2 good signal and the other one that has only 11:03:33
3 noise signal. And if I took those two 11:03:35
4 detector outputs and simply averaged them, I 11:03:37
5 would actually hurt or degrade my 11:03:40
6 signal-to-noise ratio. 11:03:42
7 Again, I'm giving you one example. 11:03:44
8 I'm not saying that's the only one out there, 11:03:46
9 but that would be one instance. And, again, 11:03:50
10 a well-designed device wouldn't do that. You 11:03:53
11 wouldn't take -- you wouldn't average in a 11:03:55
12 bad signal. 11:03:58
13 BY MR. DAVIS: 11:03:59
14 Q. When does -- go ahead. 11:03:59
15 A. I'm sorry. 11:04:00
16 But you asked is there any instance 11:04:01
17 ever where using separated, spatially 11:04:03
18 separated detectors would decrease your 11:04:06
19 signal-to-noise ratio. That's the example I 11:04:08
20 was giving. 11:04:10
21 Q. When does using change detection in a wearable 11:04:10
22 device not improve the signal-to-noise ratio? 11:04:15

1 A. Well, again, in general, change detection 11:04:30
2 does improve the signal-to-noise ratio. The 11:04:32
3 instance it wouldn't is that when the light 11:04:38
4 source is off, if for some reason the noise 11:04:41
5 level went up, and in that instance, change 11:04:43
6 detection would not necessarily help. 11:04:51
7 Again, off the top of my head, let 11:04:54
8 me give you one example. Let's say I had a 11:04:57
9 ambient light sensor of some adjacent light 11:05:02
10 source, or something, and so when you turned 11:05:05
11 the light off, the ambient light sensor said, 11:05:07
12 oh, the light is down so I'm going to 11:05:10
13 increase the background light. On that 11:05:12
14 instance, the background noise would increase 11:05:16
15 when the light source is off. 11:05:18
16 So -- 11:05:21
17 Q. When -- 11:05:22
18 A. Can be a pretty esoteric situation, but in 11:05:23
19 general, change detection does improve the 11:05:29
20 signal-to-noise ratio. 11:05:31
21 Q. When does synchronizing light emitters and 11:05:31
22 detectors in a wearable device not improve the 11:05:35

1 signal-to-noise ratio? 11:05:37
2 A. Well, again, in general, synchronizing the 11:05:44
3 light source in detectors does improve the 11:05:47
4 signal-to-noise ratio. 11:05:50
5 One example -- and, again, just off 11:05:50
6 the top of my head -- where it would not, is 11:05:52
7 if you're using -- again, giving you one 11:05:54
8 example, if you're using what's called a 11:05:59
9 lock-in amplifier where not only do you 11:06:01
10 synchronize but you also measure the phase of 11:06:04
11 the light source, and if you look at hundred 11:06:11
12 degrees -- 180 degrees out of phase, then you 11:06:19
13 would actually hurt your signal-to-noise 11:06:23
14 ratio because you're looking in the wrong 11:06:26
15 phase quadrant, if that makes sense. 11:06:28
16 But that would be one example I 11:06:30
17 might think of where you might -- 11:06:34
18 synchronization might not improve the 11:06:35
19 signal-to-noise ratio. 11:06:38
20 Q. When does increasing pulse rate in a wearable 11:06:38
21 device not improve signal-to-noise ratio? 11:06:41
22 A. Well, again, in general, increasing the -- 11:06:48

1 I'm -- so you said pulse rate? I'm sorry? 11:06:52
2 Q. Yes. 11:06:55
3 A. I'm sorry. 11:06:55
4 Q. Let me reask the question. 11:06:56
5 A. I'm sorry, please. Please. 11:06:58
6 Q. Yeah. When does increasing pulse rate in a 11:06:59
7 wearable device not improve the 11:07:02
8 signal-to-noise ratio? 11:07:05
9 A. So -- I love this. You would be a great -- 11:07:09
10 in our -- in my field, you're the kind of 11:07:15
11 person that gives what are called qualifier 11:07:17
12 exams, whether I'm qualified for my Ph.D. or 11:07:20
13 not, so I hope I pass this exam. Otherwise, 11:07:23
14 you can take my degree away. 11:07:26
15 Q. Yeah, I -- I hope not, Doctor. You're 11:07:28
16 certainly more educated than I am. Let me 11:07:31
17 just reask the question, though. 11:07:33
18 A. I'm sorry. 11:07:35
19 Q. When does increasing pulse rate in a wearable 11:07:35
20 device not improve the signal-to-noise ratio? 11:07:38
21 A. So, again, in general, increasing the pulse 11:07:42
22 repetition rate increases -- and by the way, 11:07:45

1 the reason I keep on -- when you say "pulse 11:07:50
2 rate," I keep on saying "pulse repetition 11:07:52
3 rate," is for people in physiological 11:07:54
4 measurements, when they think pulse rate, 11:07:56
5 they're thinking about heart rate. That's 11:07:58
6 the only reason I keep on repeating "pulse 11:08:00
7 repetition rate." 11:08:03
8 But anyway, the -- just -- in 11:08:03
9 general, increasing the pulse repetition rate 11:08:06
10 does increase the signal-to-noise ratio. 11:08:08
11 Example where it might not -- again, off the 11:08:11
12 top of my head -- would be where the detector 11:08:13
13 saturates because too many photons are 11:08:17
14 hitting it, or that the light source can only 11:08:20
15 deliver so much energy, so when you increase 11:08:23
16 the pulse repetition rate the pulse intensity 11:08:25
17 is actually decreasing. 11:08:28
18 Q. When does increasing light intensity in a 11:08:30
19 wearable device not improve the 11:08:33
20 signal-to-noise ratio? 11:08:34
21 A. Well, again, in general, increasing the light 11:08:40
22 intensity does increase the signal-to-noise 11:08:43

1 ratio. One example, again, sitting here 11:08:45
2 thinking off the top of my head, is if I have 11:08:47
3 a light source where increasing the light 11:08:50
4 intensity increases the noise level much 11:08:54
5 further, or higher than the signal -- light 11:08:58
6 intensity, then the signal-to-noise ratio 11:09:03
7 would actually degrade because the noise from 11:09:08
8 the light source increased higher than the -- 11:09:10
9 faster than the signal did. 11:09:13
10 Q. Do -- strike that. 11:09:14
11 Does using spatially separated 11:09:24
12 detectors in a wearable device contribute to 11:09:26
13 the signal or the noise in a signal-to-noise 11:09:30
14 ratio? 11:09:31
15 MR. CHRISTOPHER: Objection to form. 11:09:33
16 A. You would have to be a little more specific 11:09:44
17 for me to answer that question with regards 11:09:46
18 to how it's being used. If you'd like, I can 11:09:49
19 try to clarify that. 11:09:55
20 BY MR. DAVIS: 11:09:59
21 Q. Sure. 11:09:59
22 A. So let me give you two different instances -- 11:10:00

1 examples where -- let's say we have two 11:10:04
2 detectors, just to be specific, and I have -- 11:10:07
3 if I have two detectors, I'll give you one 11:10:12
4 example where it improves the signal level, 11:10:15
5 and I'll give you a different example where 11:10:17
6 it decreases the noise level. 11:10:19
7 So if I have two detectors, and 11:10:23
8 let's say that one detector is right above 11:10:30
9 where there's a blood vessel and so, 11:10:33
10 therefore, it gets a strong signal, and the 11:10:36
11 other detector is way off and -- is further 11:10:38
12 away so it gets a very poor signal level. 11:10:41
13 By selecting or by looking at all 11:10:43
14 those detectors and saying, no, I want to use 11:10:46
15 that detector that's right above the blood 11:10:48
16 vessel and, therefore, getting a strong 11:10:52
17 signal, I will have improved my 11:10:54
18 signal-to-noise ratio because I picked the 11:10:56
19 detector that had the strongest of the 11:10:57
20 signals. 11:10:59
21 That would be an instance where, by 11:11:00
22 using spatially separated detectors, I'm 11:11:02

1 improving the signal level. 11:11:05
2 An example where I would reduce the 11:11:06
3 noise level by using spatially separated 11:11:10
4 detectors -- again, take that same example -- 11:11:14
5 one detector is above the blood vessel and 11:11:17
6 the other is completely away from the blood 11:11:19
7 vessel, well -- but both detectors are seeing 11:11:22
8 the same skin and background interference, 11:11:24
9 et cetera, ambient light, skin interference, 11:11:28
10 et cetera. 11:11:31
11 So now if I take the detector that 11:11:32
12 has the strong signal and I use the other 11:11:35
13 detector to subtract out the background, 11:11:39
14 i.e., from the skin interference, the ambient 11:11:41
15 light, et cetera, then I'm reducing the noise 11:11:44
16 level. 11:11:46
17 Does that make sense? 11:11:49
18 Q. Is it your testimony that using spatially 11:11:57
19 separated detectors in a wearable device 11:11:59
20 impacts both the signal and the noise in a 11:12:04
21 signal-to-noise ratio? 11:12:07
22 MR. CHRISTOPHER: Objection to form. 11:12:09

1 A. It's my testimony that using spatially 11:12:13
2 separated detectors can improve the 11:12:20
3 signal-to-noise ratio. As to whether that 11:12:24
4 improvement occurs by improving the signal 11:12:28
5 level or by decreasing the noise level 11:12:32
6 depends on how you're using those multiple 11:12:36
7 inputs from the detectors. 11:12:40
8 BY MR. DAVIS: 11:12:43
9 Q. Prior to your patents, was it known to use 11:12:44
10 spatially separated detectors in a wearable 11:12:49
11 device? 11:12:51
12 MR. CHRISTOPHER: Objection to form 11:12:53
13 and scope. 11:12:54
14 A. I don't know of that. And maybe I should -- 11:12:55
15 I just want to put a -- if I could clarify 11:13:06
16 what I'm thinking of when I answer your 11:13:08
17 questions on, "prior to your patent on 11:13:10
18 wearable devices." 11:13:14
19 BY MR. DAVIS: 11:13:14
20 Q. Well, why don't we stick with this question 11:13:15
21 first. 11:13:17
22 A. Okay. 11:13:17

1 Q. Prior to your patents, was it known to use 11:13:18
2 spatially separated detectors in a wearable 11:13:22
3 device? 11:13:24
4 MR. CHRISTOPHER: Same objections. 11:13:25
5 A. Prior to my -- I'm sorry. The question was, 11:13:26
6 prior to my patent did people use spatially 11:13:31
7 separated detectors? Is that what you're 11:13:34
8 asking? I'm sorry. 11:13:36
9 BY MR. DAVIS: 11:13:38
10 Q. Yes. 11:13:38
11 MR. CHRISTOPHER: Same objections. 11:13:44
12 A. Yeah, I can't think of whether they were 11:13:44
13 known or not. And, again, let me -- let me 11:13:51
14 be specific in what I'm thinking just so I 11:13:54
15 put a context around that. 11:13:57
16 So, again, my patent priority date 11:13:58
17 is 2012, and before that, when I'm thinking 11:14:03
18 about wearable devices, I'm thinking of a 11:14:06
19 pulse oximeter that you put on the finger. 11:14:12
20 And so I do not know whether there 11:14:13
21 were spatially separated -- I do not -- the 11:14:21
22 pulse oximeters I knew did not have spatially 11:14:24

1 separated detectors on the pulse oximeter. 11:14:27
2 Doesn't mean that there weren't any, but the 11:14:31
3 ones I had at least, or the ones I know of, 11:14:33
4 did not have spatially separated detectors. 11:14:35
5 BY MR. DAVIS: 11:14:38
6 Q. Prior to 2012, are you aware of any other 11:14:39
7 wearable device? 11:14:41
8 MR. CHRISTOPHER: Objection to form. 11:14:42
9 A. Again, I'm going from memory. This is 11:14:51
10 obviously 14, 15 years ago. The wearable 11:14:53
11 devices that I knew about at that time were 11:15:04
12 something like the Fitbit, I think I had a 11:15:05
13 Fitbit, but that Fitbit only had an 11:15:07
14 accelerometer. 11:15:10
15 So -- I'm sorry, could you repeat 11:15:15
16 your question? Let me just say [sic] it 11:15:16
17 again. 11:15:19
18 BY MR. DAVIS: 11:15:20
19 Q. Prior to 2012, are you aware of any other 11:15:20
20 wearable device beyond a pulse oximeter? 11:15:22
21 MR. CHRISTOPHER: Objection to form. 11:15:27
22 A. Yes. 11:15:28

1 BY MR. DAVIS: 11:15:31
2 Q. What are those? 11:15:32
3 A. Well, again, in answer -- in the context of 11:15:32
4 light measuring wearable devices, that's the 11:15:38
5 oximeter that I was referring to. But, 11:15:42
6 again, at the time, I believe, or at least 11:15:49
7 what I owned, I had a Fitbit which counted 11:15:51
8 the number of steps that you took, and so 11:16:01
9 that was a wearable device that had an 11:16:02
10 accelerometer in it to measure the motion 11:16:05
11 and, therefore, how many steps you were 11:16:08
12 taking. 11:16:10
13 They famously said, you know, you're 11:16:10
14 supposed to take 10,000 steps per day, or 11:16:14
15 whatever the number was. 11:16:16
16 BY MR. DAVIS: 11:16:17
17 Q. So in the context of light measuring wearable 11:16:18
18 devices, are you aware of any other wearable 11:16:20
19 devices beyond a pulse oximeter prior to 2012? 11:16:23
20 MR. CHRISTOPHER: Objection to form 11:16:30
21 and scope. 11:16:31
22 A. I'm sure there were. Again, my experience 11:16:39

1 was in -- or my -- yeah, what I had or what I 11:16:41
2 used for pulse oximeters. But I'm sure, for 11:16:45
3 example, in a hospital there would have been 11:16:49
4 medical devices that use light to measure 11:16:52
5 physiological parameters. Whether those -- I 11:17:04
6 wouldn't call those wearables, necessarily, 11:17:05
7 although you would say that they're ones that 11:17:07
8 are applied to the body. 11:17:09
9 But if I think about a portable 11:17:10
10 device, i.e., one that you could put on your 11:17:12
11 finger or your wrist and move around with it, 11:17:15
12 the only one that comes to mind, as I sit 11:17:20
13 here, is a pulse oximeter. 11:17:22
14 BY MR. DAVIS: 11:17:26
15 Q. Prior to your patents, was it known to use 11:17:26
16 spatially separated detectors to improve 11:17:32
17 signal-to-noise ratio in the field of optical 11:17:35
18 sensing? 11:17:40
19 MR. CHRISTOPHER: Objection to form 11:17:40
20 and scope. 11:17:42
21 A. Yes. Again, to be more specific, optical 11:17:46
22 sensing, again, is very, very broad, but 11:17:52

1 the -- I'm sorry, repeat your question again. 11:17:57
2 Sorry. 11:18:01
3 BY MR. DAVIS: 11:18:03
4 Q. Prior to your patents, was it known to use 11:18:03
5 spatially separated detectors to improve 11:18:06
6 signal-to-noise ratio in the field of optical 11:18:08
7 sensing? 11:18:10
8 MR. CHRISTOPHER: Same objections. 11:18:11
9 A. Yes. It was certainly known in optical 11:18:14
10 spectroscopy, but also -- I'm sorry. The 11:18:20
11 reason I lost my train of thought, probably 11:18:22
12 partly dementia, but as I'm looking at you, I 11:18:24
13 have two eyes. I have two detectors. And so 11:18:27
14 by using both of my eyes I improve what I'm 11:18:30
15 looking at, therefore, the signal-to-noise 11:18:34
16 ratio. 11:18:38
17 So, yeah, you know, we are -- you 11:18:38
18 know, we have two eyes, right? And so by 11:18:40
19 using those two, we're able to get a better 11:18:43
20 vision of something. 11:18:49
21 BY MR. DAVIS: 11:18:50
22 Q. Prior to your patents, was it known to use 11:18:51

1 spatially separated detectors in a wearable 11:18:53
2 device to improve signal-to-noise ratio? 11:18:56
3 MR. CHRISTOPHER: Objection to form 11:19:00
4 and scope. 11:19:00
5 A. I do not know that. As I said, I'm thinking 11:19:02
6 of -- the Fitbit, I had had no light source; 11:19:09
7 it was just an accelerometer. But in the 11:19:15
8 context of oximeter, I -- you know, at least 11:19:18
9 the ones I had did not have spatially 11:19:24
10 separated detectors. 11:19:26
11 Again, they were trying to -- the 11:19:27
12 reason is because they were trying to reduce 11:19:28
13 cost, and by having one detector, that would 11:19:30
14 reduce cost. 11:19:34
15 BY MR. DAVIS: 11:19:35
16 Q. How do you tell if using spatially separated 11:19:35
17 detectors improves signal-to-noise ratio in a 11:19:40
18 wearable device? 11:19:43
19 MR. CHRISTOPHER: Objection. Outside 11:19:44
20 the scope. 11:19:55
21 A. Again, the user of a wearable device would 11:19:55
22 not know that. You would have to -- we'd 11:20:00

1 have to, again, go back to our 11:20:02
2 Gedankenexperiment, if you allow me, in a 11:20:03
3 laboratory, to take it apart and look at it 11:20:07
4 more carefully. But as a user, I don't know 11:20:10
5 whether they're improving signal-to-noise 11:20:12
6 ratio by using spatially separated detectors. 11:20:14
7 BY MR. DAVIS: 11:20:18
8 Q. In a laboratory setting, how would you 11:20:18
9 determine whether a wearable device uses 11:20:20
10 spatially separated detectors to improve 11:20:22
11 signal-to-noise ratio? 11:20:24
12 MR. CHRISTOPHER: Objection. Scope. 11:20:30
13 A. Again, go through a Gedankenexperiment. I'm 11:20:34
14 not saying -- I'm sure there are other ways 11:20:38
15 of doing it as well. 11:20:39
16 But let's say I had a wearable 11:20:40
17 device that had -- I don't know, take a 11:20:43
18 number -- four detectors. So I might 11:20:45
19 actually make a cutout where I have a hole -- 11:20:47
20 one hole and the rest blanked out. And so I 11:20:52
21 would first operate the wearable device with 11:20:54
22 all the four detectors on. And, again, I'm 11:21:00

1 assuming I have access to the signal and 11:21:03
2 noise level and, therefore, be able to 11:21:07
3 measure the signal-to-noise ratio coming out 11:21:09
4 of the processor, the detector. 11:21:10
5 And then I would first allow all 11:21:12
6 four light sources to be accessible, and then 11:21:13
7 I would purposely put this sheet of paper or 11:21:16
8 blockade where I could only let one on at 11:21:18
9 a -- allow light from one at a time only -- 11:21:21
10 I'm sorry, one detector at a time only to be 11:21:26
11 exposed and see whether -- measure that 11:21:28
12 signal-to-noise ratio and see whether it's 11:21:33
13 different than when I allowed all the 11:21:34
14 detectors on. 11:21:36
15 BY MR. DAVIS: 11:21:41
16 Q. When you use the term "Gedankenexperiment," 11:21:41
17 are you referring to a thought experiment or a 11:21:44
18 hypothetical scenario? 11:21:47
19 A. Yes. A thought experiment, a hypothetical 11:21:49
20 scenario, how I might do that lab experiment. 11:21:52
21 Q. Does comparing wavelengths in a wearable 11:21:58
22 device always improve the signal-to-noise 11:22:02

1 ratio? 11:22:04
2 MR. CHRISTOPHER: Objection to form. 11:22:05
3 A. It can in some instances, yes, but, again, 11:22:11
4 you would have to be more specific about the 11:22:19
5 signal-to-noise ratio of what you're 11:22:22
6 measuring, if I might explain that for a 11:22:25
7 moment. 11:22:28
8 BY MR. DAVIS: 11:22:29
9 Q. When does comparing wavelengths in a wearable 11:22:30
10 device improve the signal-to-noise ratio? 11:22:33
11 A. Let me give you one example when improve -- 11:22:38
12 by comparing wavelengths you could improve 11:22:40
13 the signal-to-noise ratio. 11:22:43
14 So let's say I take a look at two 11:22:44
15 wavelengths as an example. Let's say I look 11:22:52
16 at green and blue. 11:22:55
17 So green light is absorbed by blood 11:22:57
18 and, therefore, can be used -- that's the 11:23:02
19 reason your blood looks red, because it 11:23:05
20 strongly absorbs green light. Blue light is 11:23:07
21 not that much absorbed by blood, but it does 11:23:12
22 reflect off the skin. 11:23:17

1 And so if I now compare my -- if I 11:23:20
2 take the green light signal and the blue 11:23:23
3 light signal from a wearable device, I can 11:23:25
4 use the blue light to -- blue light signal to 11:23:27
5 remove some of the interferences from, for 11:23:30
6 example, the skin and, therefore, remove out 11:23:34
7 of the green light the component of the noise 11:23:40
8 that's coming from the skin interference, as 11:23:42
9 just one example. 11:23:45
10 Another example where comparing 11:23:47
11 wavelengths can improve the signal-to-noise 11:23:48
12 ratio is if you're trying to distinguish from 11:23:51
13 different constituents of blood. So 11:23:54
14 different constituents of blood might have a 11:23:55
15 different spectral peak, and so by measuring 11:23:57
16 signals that are at the peak and not at the 11:24:04
17 peak, you can improve the signal-to-noise 11:24:06
18 ratio. 11:24:12
19 Q. When does comparing wavelengths in a wearable 11:24:12
20 device not improve the signal-to-noise ratio? 11:24:15
21 MR. CHRISTOPHER: Objection to form. 11:24:19
22 A. Again, you have to say the signal-to-noise 11:24:19

1 ratio of what you're measuring. So, again, 11:24:21
2 let's say we're trying to measure -- let's 11:24:26
3 say we're trying to measure blood again or 11:24:34
4 the hemoglobin content in blood as an 11:24:36
5 example -- the blood oxygen level. I'm 11:24:41
6 sorry, blood oxygen level. 11:24:46
7 So if I have two wavelengths that 11:24:47
8 are on -- let's say on the visible side, I 11:24:54
9 may not only -- by just having those two I 11:25:01
10 may not improve my signal-to-noise ratio of 11:25:05
11 the blood oxygen measurement. 11:25:07
12 BY MR. DAVIS: 11:25:12
13 Q. Does comparing wavelengths in a wearable 11:25:12
14 device contribute to the signal or the noise 11:25:16
15 in a signal-to-noise ratio? 11:25:18
16 MR. CHRISTOPHER: Objection to form. 11:25:20
17 A. The -- again, I'll give a general answer, 11:25:21
18 but, again, you'd have to look at the 11:25:38
19 specifics of it. 11:25:40
20 But I would say, in general, when 11:25:41
21 comparing wavelengths what you're trying to 11:25:45
22 do is reduce the noise level, in general, 11:25:48

1 because what you're trying to do is, say, the 11:25:54
2 other interferences -- for example, from the 11:25:56
3 skin. An example I gave are the green and 11:25:58
4 the blue light, you are trying to remove the 11:26:01
5 noise from the skin interference by using the 11:26:02
6 blue light signal. 11:26:05
7 But, again, at the -- sitting here 11:26:07
8 at the top of my head, I think wavelength 11:26:09
9 comparison is, in general, used to improve 11:26:13
10 the signal-to-noise ratio by decreasing the 11:26:15
11 noise level or the interferences. 11:26:18
12 BY MR. DAVIS: 11:26:21
13 Q. Prior to your patents, was it known to use -- 11:26:21
14 to compare wavelengths in a wearable device to 11:26:25
15 improve the signal-to-noise ratio? 11:26:29
16 MR. CHRISTOPHER: Objection to form 11:26:31
17 and scope. 11:26:32
18 A. Could you repeat that question again? Sorry. 11:26:34
19 BY MR. DAVIS: 11:26:39
20 Q. Prior to your patents, was it known to compare 11:26:39
21 wavelengths in a wearable device to improve 11:26:43
22 the signal-to-noise ratio? 11:26:45

1 MR. CHRISTOPHER: Same objections. 11:26:51
2 A. Well, again, in the context of the oximeter 11:26:52
3 that we were talking about -- well, again, 11:26:57
4 using that example of a wearable device -- 11:27:00
5 that uses typically two wavelengths of light, 11:27:02
6 red and infrared, to measure the blood oxygen 11:27:06
7 level. 11:27:11
8 And if I only had one wavelength, 11:27:13
9 then I wouldn't get a good measurement. By 11:27:15
10 using both, it gets a more reliable 11:27:18
11 measurement of the blood oxygen level. 11:27:20
12 So in the context of an oximeter, 11:27:22
13 i.e., a device that you put on your finger, 11:27:25
14 the signal-to-noise ratio for the blood 11:27:30
15 oxygen measurement is improved by using two 11:27:32
16 wavelengths. 11:27:37
17 BY MR. DAVIS: 11:27:38
18 Q. Prior to your patents, was it known to compare 11:27:39
19 wavelengths in a wearable device to improve 11:27:42
20 the signal-to-noise ratio? 11:27:45
21 MR. CHRISTOPHER: Objection. Form 11:27:47
22 and scope. 11:27:48

1 A. Well, again, in the context of the oximeter 11:27:53
2 that we just talked about, by comparing the 11:27:56
3 two wavelengths in that particular case, red 11:27:58
4 and infrared, you're improving the 11:28:02
5 signal-to-noise ratio of the blood oxygen 11:28:08
6 level measurement. 11:28:10
7 BY MR. DAVIS: 11:28:12
8 Q. And that was known prior to your patents. 11:28:12
9 Correct? 11:28:14
10 MR. CHRISTOPHER: Same objections. 11:28:15
11 A. Yes. Prior to 2012, oximeters existed that 11:28:17
12 used red and infrared light to measure the 11:28:21
13 blood oxygen level. 11:28:24
14 BY MR. DAVIS: 11:28:27
15 Q. And those oximeters compared wavelengths to 11:28:27
16 improve the signal-to-noise ratio. Correct? 11:28:31
17 MR. CHRISTOPHER: Same objections. 11:28:32
18 A. Those oximeters used two wavelengths of light 11:28:33
19 to improve the signal-to-noise ratio of the 11:28:40
20 blood oxygen measurement. 11:28:44
21 BY MR. DAVIS: 11:28:48
22 Q. And those oximeters compare the two 11:28:48

1 wavelengths of light to improve the 11:28:50
2 signal-to-noise ratio; is that correct? 11:28:52
3 MR. CHRISTOPHER: Objection to form. 11:28:55
4 A. Again, I'm -- again, I'm trying to say, you 11:28:56
5 always have to tie a signal-to-noise ratio to 11:29:00
6 something, and so in particular, or the 11:29:03
7 signal-to-noise ratio of the blood oxygen 11:29:08
8 level. An oximeter improves the 11:29:10
9 signal-to-noise ratio of the blood oxygen 11:29:15
10 measurement, but -- I'm sorry, oxygen 11:29:17
11 measurement, by comparing two different 11:29:21
12 wavelengths. 11:29:23
13 BY MR. DAVIS: 11:29:24
14 Q. So you would agree, then, that prior to your 11:29:31
15 patents it was known in the field to compare 11:29:33
16 two or more wavelengths of light in a wearable 11:29:39
17 device to improve a signal-to-noise ratio? 11:29:42
18 MR. CHRISTOPHER: Objection to form. 11:29:45
19 A. Prior to my patent or, in particular, blood 11:29:52
20 oximeters, it was known that comparing two 11:29:59
21 different wavelengths could improve 11:30:04
22 signal-to-noise ratio for a blood oxygen 11:30:06

1 measurement. 11:30:09
2 However, I caution you that those 11:30:09
3 blood oximeters, you had to be completely 11:30:13
4 still, not move for the duration of the 11:30:15
5 measurement, which is -- even though, you 11:30:19
6 know, one would consider that a wearable in 11:30:24
7 the sense it's put on the body, it's totally 11:30:26
8 useless for something such as a watch or a 11:30:29
9 ring or an earpiece where you obviously don't 11:30:31
10 want to stay super still during the 11:30:35
11 measurement. 11:30:39
12 You know, if you -- when you go to 11:30:39
13 the doctor's office and they put the blood 11:30:41
14 oximeter on your finger, they caution you, 11:30:44
15 put your -- keep your hands still and don't 11:30:46
16 move for 30 seconds while we're doing this 11:30:48
17 measurement. 11:30:50
18 So the blood oximeters, yes, they 11:30:50
19 compared wavelengths, but they would not 11:30:52
20 allow you to move, which would be totally 11:30:54
21 useless for the context of a smart watch or 11:30:58
22 smart ring or a smart earbud or something 11:31:00

1 like that. 11:31:03
2 BY MR. DAVIS: 11:31:03
3 Q. The claims of your patents don't require the 11:31:06
4 user of the device to not move. Correct? 11:31:11
5 MR. CHRISTOPHER: Objection to form. 11:31:13
6 A. I'm sorry, say it again. I'm sorry. 11:31:14
7 BY MR. DAVIS: 11:31:16
8 Q. The claims of your patents do not require the 11:31:16
9 user of the device to not move. Correct? 11:31:18
10 MR. CHRISTOPHER: Objection to form. 11:31:20
11 A. The claims of the patent, you're asking? I'm 11:31:24
12 sorry. 11:31:29
13 BY MR. DAVIS: 11:31:29
14 Q. Yes. The claims of your patents -- 11:31:29
15 A. Yeah. 11:31:32
16 Q. -- do not require that the user is moving. 11:31:32
17 Correct? 11:31:35
18 MR. CHRISTOPHER: Objection to form. 11:31:35
19 A. The claims of the patent do not have any 11:31:36
20 reference to whether the user is moving or 11:31:43
21 not moving, if I understand your question 11:31:47
22 correctly. There is no condition placed on 11:31:50

1 the movement. 11:31:52
2 BY MR. DAVIS: 11:31:53
3 Q. So the claims of your patents cover a 11:31:54
4 situation where the user is not moving. 11:31:59
5 Correct? 11:32:01
6 MR. CHRISTOPHER: Objection to form. 11:32:03
7 A. I mean, could we -- to be more specific, 11:32:07
8 could we -- you want to put up one claim or 11:32:10
9 something we can look at to -- maybe to 11:32:12
10 direct that question? 11:32:14
11 BY MR. DAVIS: 11:32:16
12 Q. I'm asking you whether you're aware of any 11:32:16
13 limitation in your patents that requires that 11:32:19
14 the user be moving. 11:32:23
15 MR. CHRISTOPHER: Objection to form. 11:32:26
16 A. A user be moving. 11:32:27
17 So, again, even in the four 11:32:32
18 patents-in-suit we're talking about 80 11:32:38
19 claims, so I'm not sure I remember all of 11:32:39
20 them, but I -- you're asking if there's any 11:32:41
21 restrictions on movement in any of those 80 11:32:44
22 claims? Is that what you're asking? I'm 11:32:46

1 sorry. 11:32:48
2 BY MR. DAVIS: 11:32:48
3 Q. Are there limitations directed towards whether 11:32:50
4 the user of a device is moving, in your 11:32:53
5 patents? 11:32:58
6 MR. CHRISTOPHER: Objection to form. 11:32:59
7 A. Off the top of my head, out of the four 11:33:02
8 patents we're talking about, I don't remember 11:33:07
9 whether there's any -- I don't recall any 11:33:09
10 limitations related to movement of the user. 11:33:12
11 BY MR. DAVIS: 11:33:16
12 Q. In a laboratory setting, how would you 11:33:16
13 determine whether comparing wavelengths 11:33:18
14 improve the signal-to-noise ratio in a 11:33:23
15 wearable device? 11:33:25
16 MR. CHRISTOPHER: Objection to form. 11:33:26
17 It's outside the scope. 11:33:28
18 A. Well, again, in the context of a laboratory 11:33:31
19 setting, assuming for this wearable device, 11:33:38
20 again, I have access to the signal coming out 11:33:44
21 at, let's say, Wavelength 1 and Wavelength 2, 11:33:47
22 and the signal-to-noise ratio measured for 11:33:50

1 each of those two wavelengths, I could 11:33:53
2 measure -- again, in a Gedanken laboratory 11:33:55
3 setting, if I could measure the 11:33:58
4 signal-to-noise ratio for Wavelength 1 and I 11:34:00
5 could measure the signal-to-noise ratio for 11:34:03
6 Wavelength 2 separately, and then I could see 11:34:06
7 the signal-to-noise ratio for when I compare 11:34:09
8 those two wavelengths and see whether it's 11:34:15
9 improved compared to when I measured a single 11:34:17
10 wavelength. 11:34:20
11 So it would be sort of three 11:34:21
12 measurements: Signal-to-noise ratio 11:34:22
13 Wavelength 1; signal-to-noise ratio at 11:34:24
14 Wavelength 2; and then signal-to-noise ratio 11:34:26
15 when I use those two wavelengths together. 11:34:28
16 And if that is better than the 11:34:33
17 others, then I would say I have improved the 11:34:35
18 signal-to-noise ratio. 11:34:38
19 MR. DAVIS: Why don't we go off the 11:34:39
20 record. 11:34:47
21 (Off the record at 11:34 a.m.) 11:34:47
22 (Back on the record at 11:44 a.m.) 11:44:27

1 BY MR. DAVIS: 11:44:29
2 Q. Doctor, you mentioned the concept, before, of 11:44:30
3 photoplethysmography; is that correct? 11:44:34
4 A. Yes. Photoplethysmography, often abbreviated 11:44:36
5 PPG. 11:44:42
6 Q. Yes. Is it -- 11:44:42
7 A. It is a bit -- it is a bit of a tongue 11:44:43
8 twister, so "PPG" is good. 11:44:46
9 Q. I agree. What is -- what is PPG? 11:44:50
10 A. PPG is basically the fact that blood absorbs 11:44:53
11 light, and so you can measure blood, either 11:45:01
12 the volume or the change in blood, by looking 11:45:09
13 at the light signal. Because when there's 11:45:14
14 more blood there's less light either 11:45:19
15 transmitted -- when there's more blood more 11:45:21
16 light is absorbed, and, therefore, there's 11:45:23
17 less light either transmitted or received -- 11:45:25
18 or reflected. 11:45:27
19 And, likewise, if there's less 11:45:30
20 blood, there's more light transmitted or 11:45:32
21 reflected. 11:45:33
22 So, again, PPG, in general, refers 11:45:34

1 to the fact that light is absorbed by blood 11:45:40
2 and, therefore, by measuring the light you 11:45:42
3 can measure the blood volume or change in 11:45:44
4 blood. 11:45:47
5 Q. Was PPG first discovered around the 1930s? 11:45:48
6 A. Your history is probably better than mine. 11:45:56
7 You might be right. It is well-known for a 11:45:58
8 long time. 11:46:01
9 And just coincidentally, it's also 11:46:08
10 the basis of pulse oximeter. So I think 11:46:10
11 you're probably right, around that -- that's 11:46:14
12 around the time when pulse oximetry was first 11:46:15
13 discovered. 11:46:18
14 Q. Do you know when people started using multiple 11:46:18
15 different light sources with PPG? 11:46:21
16 MR. CHRISTOPHER: Objection to form 11:46:24
17 and scope. 11:46:25
18 A. Again, a pulse oximeter -- again, what I know 11:46:33
19 about is, really, pulse oximeters, and pulse 11:46:38
20 oximeters would be an example where multiple 11:46:42
21 light sources, i.e. -- well, I'm sorry, let 11:46:44
22 me take that back. 11:46:46

1 Repeat your question again. Sorry. 11:46:47
2 BY MR. DAVIS: 11:46:51
3 Q. Sure. 11:46:51
4 Do you know when people started using 11:46:57
5 multiple different light sources with PPG? 11:46:58
6 MR. CHRISTOPHER: Same objections. 11:47:03
7 A. I don't know precisely when that started, but 11:47:10
8 I think probably around the time that -- and 11:47:15
9 I don't know exactly when that was, when 11:47:19
10 light-emitting diodes started being used 11:47:21
11 within pulse oximeters. That's probably 11:47:24
12 around the time when they were using two 11:47:27
13 different light sources. 11:47:29
14 BY MR. DAVIS: 11:47:30
15 Q. Was that in the 1980s? 11:47:31
16 MR. CHRISTOPHER: Objection to form. 11:47:33
17 A. It may be. I don't know exactly. 11:47:34
18 BY MR. DAVIS: 11:47:36
19 Q. Prior to your patents, it was known to use 11:47:36
20 multiple different light sources when 11:47:46
21 performing PPG. Right? 11:47:47
22 MR. CHRISTOPHER: Objection to form 11:47:50

1 and scope. 11:47:51
2 A. Prior to my patent, I believe it was known in 11:47:56
3 the field of oximeters, i.e., devices you put 11:47:59
4 on your finger but you can't move while in 11:48:02
5 the hospital or nurse's setting. They 11:48:04
6 probably use multiple light sources to do 11:48:12
7 pulse oximetry. 11:48:15
8 BY MR. DAVIS: 11:48:17
9 Q. And prior to your patents, it was known to 11:48:17
10 analyze blood with spectroscopy; is that 11:48:25
11 correct? 11:48:27
12 MR. CHRISTOPHER: Same objections. 11:48:30
13 A. Yes. Prior to my patent, it was known that 11:48:32
14 blood -- different blood constituents could 11:48:39
15 be measured using spectroscopy. 11:48:41
16 BY MR. DAVIS: 11:48:46
17 Q. Prior to your patents, it was known to use 11:48:46
18 optical filters for spectroscopy? 11:48:48
19 MR. CHRISTOPHER: Same objections. 11:48:51
20 A. I'm sorry, your question was, are pulse -- 11:49:01
21 are filters using optical spectroscopy; is 11:49:03
22 that correct? 11:49:07

1 BY MR. DAVIS: 11:49:07
2 Q. Prior to your patents, it was known to use 11:49:08
3 optical filters for spectroscopy? 11:49:10
4 MR. CHRISTOPHER: Objection to form 11:49:12
5 and scope. 11:49:12
6 A. Yes. 11:49:17
7 BY MR. DAVIS: 11:49:17
8 Q. Prior to your patents, it was known -- 11:49:17
9 A. Prior to my patent -- prior to my patent, it 11:49:19
10 was known to use filters in optical 11:49:21
11 spectroscopy. 11:49:27
12 Q. Apologies. Prior to your patents, it was 11:49:28
13 known to use optical detectors for 11:49:30
14 spectroscopy? 11:49:33
15 MR. CHRISTOPHER: Objection to form 11:49:34
16 and scope. 11:49:35
17 A. Prior to my patents, it was known to use -- 11:49:38
18 I'm sorry, what did you say again? I 11:49:48
19 apologize. 11:49:50
20 BY MR. DAVIS: 11:49:50
21 Q. Yeah. Prior to your patents, it was known to 11:49:50
22 use optical detectors for spectroscopy. 11:49:52

1 A. Okay. Sorry. 11:49:59
2 MR. CHRISTOPHER: Same objections. 11:50:00
3 A. Prior -- 11:50:00
4 MR. CHRISTOPHER: Go ahead. 11:50:05
5 A. Prior to my patents, it was known to use 11:50:05
6 optical detectors in optical spectroscopy. 11:50:07
7 BY MR. DAVIS: 11:50:11
8 Q. And prior to your patents, it was known to use 11:50:11
9 filters for optical detectors for 11:50:13
10 spectroscopy? 11:50:17
11 MR. CHRISTOPHER: Objection to form 11:50:18
12 and scope. 11:50:19
13 A. Prior to my patent, it was known to use 11:50:22
14 optical filters with detectors in optical 11:50:28
15 spectroscopy. 11:50:32
16 BY MR. DAVIS: 11:50:49
17 Q. Prior to your patents, was it conventional to 11:50:49
18 compare signals at different wavelengths? 11:50:52
19 MR. CHRISTOPHER: Objection to form. 11:50:54
20 Scope. 11:50:55
21 A. I'm sorry, what does "conventional" mean, 11:51:00
22 sorry, in this context? Could you be more 11:51:02

1 specific? 11:51:06
2 BY MR. DAVIS: 11:51:07
3 Q. Yes. Can you -- what does "conventional" mean 11:51:07
4 to you? 11:51:09
5 A. "Conventional," again, without a context, 11:51:13
6 that's too open-ended, I guess. I mean, what 11:51:16
7 do you mean "conventional"? Conventional for 11:51:20
8 what? 11:51:23
9 BY MR. DAVIS: 11:51:23
10 Q. In optical sensing, prior to your patents, was 11:51:24
11 it conventional to compare signals of light at 11:51:26
12 different wavelengths? 11:51:29
13 MR. CHRISTOPHER: Objection. Form 11:51:30
14 and scope. 11:51:31
15 A. Specifically in the field of optical 11:51:37
16 spectroscopy, comparing wavelengths was 11:51:51
17 known. In the more broad field of optical 11:51:53
18 sensing -- again, we look at our own eyes as 11:51:55
19 an example of optical sensing -- we can 11:51:58
20 contrast the difference of, you know, in the 11:52:00
21 morning I have a banana and I'd like to have 11:52:05
22 a nice, yellow banana, but sometimes when 11:52:08

1 it's really black I don't like it because 11:52:11
2 it's overly ripe or whatever. 11:52:13
3 So, yeah, we use our eyes to see 11:52:15
4 differences in color. 11:52:18
5 BY MR. DAVIS: 11:52:25
6 Q. Is the -- strike that. 11:52:25
7 Is spectroscopy used by wearable 11:52:26
8 devices? 11:52:30
9 MR. CHRISTOPHER: Objection to form 11:52:30
10 and scope. 11:52:31
11 A. Again, that's a very broad question. I'm not 11:52:37
12 sure -- could you be more specific? 11:52:39
13 BY MR. DAVIS: 11:52:43
14 Q. In what way? 11:52:44
15 A. I mean, give an example. If we refer to a 11:52:49
16 wearable device being a Fitbit that had -- 11:52:52
17 you know, from 2010 or 2011, that had an 11:52:54
18 accelerometer, that didn't use spectroscopy, 11:52:59
19 so... 11:53:01
20 Q. In an optical physiological monitoring device, 11:53:02
21 is spectroscopy used? 11:53:05
22 MR. CHRISTOPHER: Objection to form 11:53:08

1 and scope. 11:53:14
2 A. In an optical physiological measurement 11:53:15
3 device, spectroscopy may be used, it may not 11:53:17
4 be used. Depends on what you're doing. 11:53:22
5 BY MR. DAVIS: 11:53:25
6 Q. If you have a device that measures heart rate, 11:53:29
7 is that using spectroscopy? 11:53:35
8 MR. CHRISTOPHER: Objection to form. 11:53:37
9 Scope. 11:53:37
10 A. So I want to make sure I understand what 11:53:41
11 you're defining as "spectroscopy." Are you 11:53:47
12 defining "spectroscopy" as comparing two 11:53:53
13 different wavelengths? 11:53:55
14 BY MR. DAVIS: 11:53:57
15 Q. How do you use the word "spectroscopy"? 11:53:58
16 A. Well, that's a term that's -- we defined in 11:54:04
17 the patent. Can we look at the definition in 11:54:08
18 the patent or stay within the context of this 11:54:10
19 or... 11:54:10
20 Q. Yeah, I'm asking you how you use the term 11:54:15
21 "spectroscopy." 11:54:18
22 A. You know, again, I can -- I'd have to look at 11:54:18

1 the patent exactly how we defined it 11:54:20
2 specifically in the patent, but for the 11:54:22
3 moment here, for the discussion here, let me 11:54:24
4 define "optical spectroscopy" as comparing 11:54:27
5 two different wavelengths. 11:54:30
6 So in the context of comparing two 11:54:32
7 different wavelengths, if you're asking me is 11:54:34
8 that used for heart rate monitoring -- is 11:54:36
9 that correct? Is that what you're asking? 11:54:39
10 Q. Yes. 11:54:40
11 MR. CHRISTOPHER: Same objection. 11:54:42
12 A. It may be, it may not be, again, defining 11:54:48
13 "optical spectroscopy" as comparing two 11:54:51
14 different wavelengths. And let me give you 11:54:53
15 an example. 11:54:56
16 So, again, going back to the 11:54:57
17 wearable of an optical oximeter or 11:54:59
18 oximeter -- pulse oximeter, that measures two 11:55:02
19 different wavelengths to measure blood oxygen 11:55:06
20 content, but at the same time it sort of, for 11:55:11
21 free, gives you the heart rate. So in that 11:55:16
22 instance, you're getting the heart rate sort 11:55:19

1 of for free when you're doing oximetry. 11:55:23
2 On the other hand, I can use just 11:55:26
3 one wavelength of light, such as green light 11:55:28
4 or even infrared light, to measure the 11:55:30
5 pulse -- the heartbeat or the pulse rate 11:55:33
6 without using two different wavelengths of 11:55:38
7 light and, therefore, would not require 11:55:43
8 spectroscopy. 11:55:47
9 BY MR. DAVIS: 11:55:47
10 Q. Prior to your patents, the concept of using a 11:55:47
11 wearable device to monitor heart rate was 11:55:51
12 known. Correct? 11:55:53
13 MR. CHRISTOPHER: Objection to form. 11:55:57
14 Outside the scope. 11:55:58
15 A. Well, as I said, if we define -- a pulse 11:56:01
16 oximeter is a wearable device and I'm 11:56:07
17 defining it as a wearable device even though 11:56:09
18 you could not move with it or you could not 11:56:12
19 do a move -- you could not move while doing a 11:56:15
20 measurement, in the context of a wearable 11:56:19
21 device, yes -- I'm sorry, the pulse 11:56:21
22 oximeter -- yes, the pulse oximeter gives you 11:56:26

1 the heart rate measurement, and that was 11:56:30
2 known before my patent. 11:56:31
3 But, again, you had to be completely 11:56:32
4 still during the measurement. 11:56:35
5 BY MR. DAVIS: 11:56:39
6 Q. Prior to your patents, the concept of using a 11:56:39
7 wearable device to measure pulse oximetry was 11:56:41
8 known. Correct? 11:56:45
9 MR. CHRISTOPHER: Objection to form. 11:56:46
10 Scope. 11:56:47
11 A. Well, again, defining a wearable device as 11:56:50
12 being a -- an example of a wearable device 11:56:54
13 being a pulse oximeter used in, for example, 11:56:57
14 a hospital or a doctor's office, it was known 11:56:59
15 to measure the blood oxygen level using a 11:57:02
16 wearable device. But, again, that 11:57:06
17 measurement had to be done with you sitting 11:57:08
18 completely still for, whatever, the 30 11:57:10
19 seconds of the measurement. 11:57:12
20 BY MR. DAVIS: 11:57:13
21 Q. So you would agree that wearable heart rate 11:57:17
22 monitors were on the market by -- before your 11:57:20

1 patents. Correct? 11:57:22
2 MR. CHRISTOPHER: Objection to form. 11:57:23
3 Outside the scope. 11:57:24
4 A. I agree that if we consider a pulse oximeter 11:57:28
5 to be a wearable device, it was known to 11:57:32
6 measure the blood oxygen, but, again, could 11:57:34
7 only be measured if you were super still 11:57:39
8 during the measurement time. 11:57:41
9 BY MR. DAVIS: 11:57:44
10 Q. Just to direct you back to my question, 11:57:46
11 Doctor, you would agree that wearable heart 11:57:48
12 rate monitors were on the market before your 11:57:54
13 patents. Correct? 11:57:56
14 MR. CHRISTOPHER: Same objections. 11:57:57
15 A. Again, considering wearable device to be, in 11:57:59
16 this case, a pulse oximeter, it was known 11:58:04
17 that the wearable device, i.e., the pulse 11:58:07
18 oximeter, could measure a heart rate, but, 11:58:10
19 again, you had to be super still during the 11:58:12
20 time of the measurement. 11:58:15
21 BY MR. DAVIS: 11:58:16
22 Q. Doctor, I was asking about heart rate monitor. 11:58:19

1 Are you -- 11:58:22
2 A. I'm sorry. 11:58:24
3 Q. -- referring to pulse oximeter intentionally, 11:58:24
4 or... 11:58:28
5 A. Well, no, the pulse oximeter gives you heart 11:58:29
6 rate. 11:58:30
7 Q. Okay. So just generally, would you agree that 11:58:32
8 wearable heart rate monitors were on the 11:58:35
9 market prior to your patents? Correct? 11:58:38
10 MR. CHRISTOPHER: Same objections. 11:58:39
11 A. Prior to my patent, oximeters being an 11:58:43
12 example of a wearable device that can measure 11:58:48
13 heart rate, they were known and available on 11:58:53
14 the market; however, again, to do that, 11:58:56
15 during the measurement time you had to be 11:58:58
16 super still. 11:59:00
17 BY MR. DAVIS: 11:59:02
18 Q. Prior to your patents, what other wearable 11:59:03
19 devices were on the market for measuring heart 11:59:05
20 rate? 11:59:12
21 MR. CHRISTOPHER: Objection to form. 11:59:15
22 A. I'm sorry, could you repeat your question? I 11:59:16

1 was thinking -- say that again, please. 11:59:28
2 Sorry. 11:59:31
3 BY MR. DAVIS: 11:59:31
4 Q. Prior to your patents, what wearable devices 11:59:31
5 for measuring heart rate were on the market? 11:59:35
6 MR. CHRISTOPHER: Same objection. 11:59:37
7 A. There were other wearable devices that were 11:59:38
8 available for measuring heart rate of the 11:59:40
9 person. 11:59:45
10 BY MR. DAVIS: 11:59:46
11 Q. What were they? 11:59:46
12 A. One example -- I'm sure we all had this -- a 11:59:49
13 Polar chest strap, or chest straps in 11:59:53
14 general. So these are things that are based 11:59:55
15 on EKG or ECG. They're called 11:59:57
16 electrocardiogram, looking at the electrical 12:00:01
17 signals to measure the heart rate. Because 12:00:03
18 every time your heart beats there's an 12:00:05
19 electrical signal that causes the heartbeat, 12:00:07
20 and so you can measure the EKG signal or ECG 12:00:10
21 signal to measure heart rate on a wearable 12:00:14
22 device such as a Polar chest strap. 12:00:16

1 Q. Are you aware of any other products that were 12:00:19
2 on the market prior to your patents that were 12:00:22
3 wearable devices and measured heart rate? 12:00:26
4 A. Well, as I said, there were the pulse 12:00:28
5 oximeters, there were the EKG such as the 12:00:37
6 Polar chest strap -- I'm just -- because I 12:00:41
7 have a Polar chest strap, I just remember 12:00:43
8 that. And when exercising, if you wanted to 12:00:44
9 measure your heart, you would look at that. 12:00:47
10 There were also -- I wouldn't call 12:00:49
11 them wearable devices, but, you know, on 12:00:51
12 the -- on things like your treadmill there 12:00:52
13 are those contacts where you put your hands 12:00:55
14 on and you can measure the EKG signal and get 12:00:59
15 the heart rate from that, so -- 12:01:01
16 But, again, that's not a wearable 12:01:04
17 device. That's on the -- that's on the 12:01:05
18 treadmill, as an example. 12:01:07
19 Q. Can you think of any other products that were 12:01:09
20 on the market prior to your patents that were 12:01:11
21 wearable devices and measured heart rate? 12:01:15
22 A. Sitting here, I can't think of another 12:01:26

1 device. Those are the ones that I know of or 12:01:34
2 had. I'm sure there are other things in a 12:01:36
3 hospital setting that might be -- you know, 12:01:37
4 or things where people would put on -- a 12:01:40
5 nurse would put on your finger or something 12:01:42
6 to measure something. I don't know if you 12:01:44
7 would consider that a wearable device, but 12:01:46
8 usually they're tethered with wires and 12:01:48
9 whatnot to other instruments. 12:01:51
10 Q. By two thousand and -- excuse me. By -- prior 12:01:53
11 to your patents -- strike that. 12:02:00
12 Prior to your patents, it was already 12:02:03
13 known that you could use LEDs to measure 12:02:05
14 oxygen level in blood as part of a wearable 12:02:10
15 device; is that correct? 12:02:14
16 MR. CHRISTOPHER: Objection to form. 12:02:14
17 Scope. 12:02:15
18 A. I believe it was known that in pulse 12:02:20
19 oximeters -- assuming, again, that we're 12:02:24
20 describing pulse oximeters as a wearable 12:02:25
21 device -- there were pulse oximeters that had 12:02:31
22 light-emitting diodes in it to measure 12:02:32

1 physiological parameters such as blood oxygen 12:02:36
2 level, but, again, they would -- all of those 12:02:39
3 devices would require you to be super still 12:02:40
4 during the measurement. 12:02:43
5 BY MR. DAVIS: 12:02:48
6 Q. And prior to your patents, it was known that 12:02:48
7 you could use LEDs to measure heart rate as 12:02:50
8 part of a wearable device. Correct? 12:02:52
9 MR. CHRISTOPHER: Objection to form. 12:02:55
10 Scope. 12:02:56
11 A. Again, considering the pulse oximeter as a 12:02:59
12 wearable device, and, again, as you said, at 12:03:04
13 least, you know, by 2000 there were probably 12:03:07
14 pulse oximeters that had LEDs in it, pulse 12:03:13
15 oximeter gives you pulse rate or pulse heart 12:03:16
16 rate as well, and so, therefore, yes, LEDs 12:03:20
17 could be used to measure heart rate in a 12:03:22
18 pulse oximeter but you had to be super still 12:03:25
19 during the measurement. 12:03:28
20 BY MR. DAVIS: 12:03:29
21 Q. Had you used the pulse oximeters prior to your 12:03:30
22 patents? 12:03:39

1 MR. CHRISTOPHER: Objection to form. 12:03:39
2 Scope. 12:03:40
3 A. Yes. I know that every time when you go for 12:03:46
4 your physical or your doctor's office, the 12:03:49
5 very first thing they do before they -- you 12:03:51
6 see the doctor is they put a pulse oximeter 12:03:54
7 on your finger and say don't move for 30 12:03:56
8 seconds while we're doing that measurement, 12:03:59
9 along with measuring your temperature, your 12:04:01
10 weight, your height. So that's all part of 12:04:03
11 standard medical measurement routine. 12:04:06
12 BY MR. DAVIS: 12:04:08
13 Q. What work had you done with pulse oximeters 12:04:09
14 before your work on these patents? 12:04:10
15 MR. CHRISTOPHER: Objection. Form. 12:04:15
16 Scope. 12:04:15
17 A. I don't remember other than potentially, you 12:04:19
18 know, again wearing it in a doctor's office. 12:04:28
19 BY MR. DAVIS: 12:04:35
20 Q. With your -- strike that. 12:04:36
21 Have you studied pulse oximeters that 12:04:44
22 existed prior to your patents? 12:04:46

1 MR. CHRISTOPHER: Same objections. 12:04:49
2 A. No. I mean, I was generally aware of them, 12:04:53
3 but I had -- I don't know, when you say 12:04:56
4 "study," taken apart or anything like that, I 12:04:57
5 haven't really, you know, done a deep dive 12:05:00
6 into pulse oximeters. 12:05:04
7 BY MR. DAVIS: 12:05:06
8 Q. Have you studied wearable devices that existed 12:05:07
9 prior to your patents? 12:05:10
10 MR. CHRISTOPHER: Same objections. 12:05:12
11 A. Well, as I said, I was aware of wearable 12:05:16
12 devices such as pulse oximeters prior to my 12:05:21
13 patent. I was aware of wearable devices such 12:05:24
14 as a Fitbit that had an accelerometer in it, 12:05:30
15 but I hadn't done deep dive on any of those. 12:05:36
16 BY MR. DAVIS: 12:05:45
17 Q. Prior to your patents, were LEDs commonly used 12:05:45
18 as a light source for optical physiological 12:05:48
19 monitoring devices? 12:05:50
20 MR. CHRISTOPHER: Objection to form. 12:05:51
21 Scope. 12:05:52
22 A. Well, again, as we said before, LEDs were, I 12:06:00

1 believe, used, certainly by 2000 or so, in 12:06:04
2 pulse oximeters. And so the use of LEDs in a 12:06:09
3 wearable device were -- again, at least in a 12:06:15
4 pulse oximeter setting, were known to be 12:06:17
5 used, but, again, you had to be super still 12:06:19
6 during the measurements. 12:06:21
7 BY MR. DAVIS: 12:06:24
8 Q. Prior to your patents, were detectors such as 12:06:24
9 photodiodes commonly used to capture the light 12:06:33
10 signal for physiological monitoring devices? 12:06:36
11 MR. CHRISTOPHER: Objection. Form. 12:06:38
12 Outside the scope. 12:06:39
13 A. I'm sorry, could you repeat that question 12:06:42
14 again, please? 12:06:44
15 BY MR. DAVIS: 12:06:44
16 Q. Sure. Prior to your patents, were detectors 12:06:44
17 such as photodiodes commonly used to capture 12:06:48
18 the light signal for physiological monitoring 12:06:52
19 devices? 12:06:55
20 MR. CHRISTOPHER: Same objections. 12:06:56
21 A. Again, prior to my patent in the context of, 12:06:59
22 for example, a pulse oximeter as being a 12:07:05

1 wearable device, an optical detector is used 12:07:09
2 in a pulse oximeter to measure the light for 12:07:11
3 the physiological measurement. 12:07:13
4 But, again, in the context of the 12:07:16
5 pulse oximeter, and, again, you had to be 12:07:18
6 super still during the measurement. 12:07:19
7 BY MR. DAVIS: 12:07:28
8 Q. The LEDs that are used as a light source in 12:07:29
9 optical physiological monitoring devices, 12:07:32
10 could they -- were they known to be arranged 12:07:36
11 in various different shapes prior to your 12:07:41
12 patents? 12:07:44
13 MR. CHRISTOPHER: Objection to form. 12:07:44
14 Outside of scope of the declaration. 12:07:45
15 A. I'm sorry, I don't know what you mean by 12:07:51
16 "shapes." 12:07:54
17 BY MR. DAVIS: 12:07:55
18 Q. Let me reask the question. 12:07:56
19 Prior to your patents, was it known 12:08:00
20 that LEDs used as a light source for optical 12:08:01
21 physiological monitoring devices could be 12:08:06
22 arranged in different ways on the devices? 12:08:09

1 MR. CHRISTOPHER: Same objections. 12:08:12
2 A. I don't know the answer to that question 12:08:21
3 because I don't know -- I don't know. I 12:08:23
4 mean, again, thinking in the context of a 12:08:28
5 wearable device such as an oximeter, I don't 12:08:30
6 know why you would have multiple LEDs 12:08:32
7 arranged in a different way to measure. Just 12:08:35
8 going to put it on the finger, so... 12:08:41
9 BY MR. DAVIS: 12:08:44
10 Q. Well, you testified before that, prior to your 12:08:45
11 patents, it was known that light sources in a 12:08:48
12 wearable device could be spatially separated. 12:08:57
13 Correct? 12:09:02
14 MR. CHRISTOPHER: Objection to form. 12:09:02
15 A. I'm sorry, you said that I testified that it 12:09:12
16 was known that separated light sources could 12:09:14
17 be used in a wearable device? Did you -- is 12:09:18
18 that what you said? 12:09:22
19 BY MR. DAVIS: 12:09:23
20 Q. Yes. 12:09:23
21 A. I don't recall saying that because, again, 12:09:23
22 I'm thinking of the oximeter and I'm not 12:09:26

1 sure -- I'm sorry, did you say light sources 12:09:28
2 or detector? Now I am confused, I'm sorry. 12:09:34
3 Say that again. I'm sorry. 12:09:36
4 Q. No problem. 12:09:38
5 A. I'm confused. 12:09:38
6 Q. Let me just reask the question. 12:09:41
7 Prior to your patents, it was known 12:09:43
8 to spatially separate light sources in a 12:09:48
9 wearable device. Correct? 12:09:52
10 MR. CHRISTOPHER: Objection to form. 12:09:54
11 It's outside the scope. 12:09:55
12 A. Prior to my patent -- and, again, defining an 12:10:05
13 optical oximeter -- I'm sorry, pulse oximeter 12:10:08
14 as an optical wearable -- or a wearable 12:10:12
15 device, it was known that two different light 12:10:14
16 sources would be used, i.e., one in the 12:10:19
17 visible, one in the infrared, and very likely 12:10:23
18 they were two separate LEDs and, therefore, 12:10:26
19 were two spatially separated light sources 12:10:34
20 used in those pulse oximeters. 12:10:36
21 But, again, the pulse oximeter had 12:10:39
22 to be used with the user being super still 12:10:41

1 during the measurement. 12:10:44
2 BY MR. DAVIS: 12:10:45
3 Q. Was it known prior to your patents to use 12:10:46
4 three different light sources in a wearable 12:10:51
5 device? 12:10:54
6 MR. CHRISTOPHER: Objection to form 12:10:55
7 and scope. 12:10:58
8 A. I don't know, to be honest. I know that a 12:11:01
9 pulse oximeter, again, defined as a wearable 12:11:05
10 device, used two wavelengths. I do not know 12:11:07
11 if three wavelengths were used in those 12:11:10
12 devices. They might have, they might not 12:11:13
13 have. I just don't know. But they certainly 12:11:18
14 had to use two. Again, one typically in the 12:11:21
15 visible, and one typically in the infrared. 12:11:23
16 BY MR. DAVIS: 12:11:28
17 Q. What is the concept of ambient subtraction? 12:11:35
18 MR. CHRISTOPHER: Objection to form. 12:11:43
19 A. I'm sorry, do you mean ambient light 12:11:44
20 subtraction, or what do you -- could you 12:11:46
21 clarify what -- ambient what? 12:11:49
22 BY MR. DAVIS: 12:11:50

1 Q. Sure. What is ambient light subtraction? 12:11:51
2 MR. CHRISTOPHER: Objection to form. 12:11:55
3 A. So ambient light subtraction, to me, would be 12:11:59
4 that I'm somehow taking out the ambient light 12:12:05
5 effects. So we talked earlier about -- as an 12:12:09
6 example, we talked earlier about change 12:12:11
7 detection, and so in something like change 12:12:14
8 detection, when your local light source -- or 12:12:17
9 your -- the light source for your measurement 12:12:22
10 is off, you're measuring all the effects from 12:12:24
11 the ambient light and other things and you're 12:12:26
12 subtracting that out when you do the change 12:12:30
13 detection. 12:12:32
14 So, again, in short, ambient light 12:12:33
15 subtraction to me is you're, by some means 12:12:36
16 such as change detection -- doesn't have to 12:12:40
17 be change detection necessarily -- you're 12:12:42
18 subtracting out the ambient light effect, and 12:12:44
19 ambient light being the background light, 12:12:48
20 whether it be sunlight, room light, what have 12:12:49
21 you. 12:12:52
22 BY MR. DAVIS: 12:13:12

1 Q. Do you believe that you were the first person 12:13:13
2 to invent a wearable device based on optical 12:13:14
3 sensors that can measure the heart rate of an 12:13:19
4 individual? 12:13:21
5 MR. CHRISTOPHER: Objection to form 12:13:23
6 and it's outside the scope. 12:13:24
7 A. Well, as I said, we've been talking about 12:13:29
8 wearable device example being a pulse 12:13:32
9 oximeter, and a pulse oximeter measures heart 12:13:34
10 rate. Again, but you have to be super still 12:13:36
11 during the measurement. 12:13:39
12 BY MR. DAVIS: 12:13:40
13 Q. Do you think you invented that concept of a 12:13:50
14 wearable device, based on optical sensors, 12:13:51
15 that allows the user to move? 12:13:55
16 MR. CHRISTOPHER: Same objections. 12:14:02
17 A. What I invented are methods of improving the 12:14:14
18 signal-to-noise ratio for optical 12:14:18
19 measurements such as physiological 12:14:22
20 measurements. 12:14:24
21 Now, why do you need to increase -- 12:14:28
22 why do you need to improve the 12:14:29

1 signal-to-noise ratio? 12:14:31
2 Again, wear -- wearable devices such 12:14:32
3 as oximeters whereas you could measure heart 12:14:42
4 rate, you could measure blood oxygen 12:14:44
5 symmetry, but number one, it was in the 12:14:46
6 context of a fixed room or a doctor's 12:14:48
7 hospital -- either a hospital or doctor's 12:14:51
8 office setting, a fixed room; and number two, 12:14:54
9 that during the measurement, the patient had 12:14:56
10 to be super still. 12:14:59
11 And so there's some key -- as you 12:15:03
12 move to wearable devices that might be worn, 12:15:05
13 for example, on the wrist or finger or ear of 12:15:12
14 the user, the problems that you had to solve 12:15:17
15 included motion artifact compensation, 12:15:19
16 ambient light sensitivity, and actually, the 12:15:22
17 other one which even oximeters suffer from, 12:15:27
18 which is skin tone, being agnostic to skin 12:15:29
19 tone. 12:15:32
20 And so all of these really, from an 12:15:33
21 engineering standpoint, boil down to whether 12:15:35
22 it's because of motion or whether it's 12:15:39

1 because of ambient light or variations or 12:15:42
2 because of different skin tones. All of 12:15:47
3 these are increased sources of noise and, 12:15:50
4 therefore, to get a reliable measurement of 12:15:56
5 the physiological parameter you had to 12:16:00
6 improve your signal-to-noise ratio. 12:16:03
7 Because when we left that doctor's 12:16:04
8 office or that hospital setting where you 12:16:07
9 were super still in a fixed lighting 12:16:09
10 environment, we got all these additional 12:16:12
11 noise sources that had to be overcome by 12:16:16
12 having a better signal-to-noise ratio. 12:16:20
13 BY MR. DAVIS: 12:16:23
14 Q. What's the concept of modulations? 12:16:23
15 MR. CHRISTOPHER: Objection to form. 12:16:26
16 A. Modulation -- again, are we talking about 12:16:32
17 modulation of the light source, or what are 12:16:35
18 we talking about? 12:16:38
19 BY MR. DAVIS: 12:16:39
20 Q. In the context of your patents, what's the 12:16:39
21 concept -- what is your concept of modulation? 12:16:41
22 MR. CHRISTOPHER: Objection to form. 12:16:44

1 A. Well, again, we have to be more specific. 12:16:45
2 We're talking about modulation of the light 12:16:48
3 source, or... 12:16:50
4 BY MR. DAVIS: 12:16:51
5 Q. Sure. 12:16:51
6 A. A modulation of a light source would be to 12:16:51
7 change some parameter of the light source as 12:16:54
8 a function of time. 12:16:59
9 MR. DAVIS: Can we go off the record? 12:17:14
10 MR. CHRISTOPHER: Sure. 12:17:16
11 (Off the record at 12:27 p.m.) 12:27:40
12 (Back on the record at 12:27 p.m.) 12:27:40
13 MR. DAVIS: I don't have any further 12:27:41
14 questions at this time. We can go off the 12:27:45
15 record. 12:27:46
16 (Off the record at 12:27 p.m.) 12:27:47
17 (Back on the record at 12:33 p.m.) 12:33:01
18 MR. CHRISTOPHER: I have no questions 12:33:01
19 for Dr. Islam. We'll reserve the right to 12:33:03
20 read and sign the transcript, and with that, I 12:33:06
21 think we're done. 12:33:10
22 (Proceedings concluded at 12:33 p.m.)

1 CERTIFICATE OF NOTARY

2

3 STATE OF MICHIGAN)
) SS
4 COUNTY OF OAKLAND)

5

6 I, ALISON WEBSTER, stenographic
reporter and notary public in and for the
7 state of Michigan do hereby certify:
That the deposition of MOHAMMED
8 ISLAM, Sc.D. was taken before me via
videoconference on the date hereinbefore set
9 forth; that the foregoing questions and
answers were recorded by me stenographically
10 and reduced to computer transcription; that
this is a true, full, and correct transcript
11 of my stenographic notes so taken; and that
I am not related to, nor of counsel to,
12 either party nor interested in the event of
this cause.
13 I further certify that the adverse
party was represented by counsel at the
14 deposition.
I further certify that the deposition
15 of MOHAMMED ISLAM, Sc.D., occurred via Zoom
videoconference on Thursday, July 23, 2026,
16 commencing at 9:19 a.m., and ending at 12:33
p.m.
17

18

19

20 Alison C. Webster

21 _____
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22 Notary Public, Oakland County, Michigan
My commission expires: May 1, 2029

1 ACKNOWLEDGMENT OF DEPONENT
2
3
4
5 I, MOHAMMED ISLAM, Sc.D., do hereby
6 acknowledge that I have read and examined the
7 foregoing testimony and the same is a true,
8 correct, and complete transcription of the
9 testimony given by me and any corrections
10 appear on the attached errata sheet signed by
11 me.
12
13
14
15
16
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18
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21 _____ _____
22 (SIGNATURE) (DATE)

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