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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

April 16, 2020

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APPLICATION NUMBER: *62/826,536*
FILING DATE: *March 29, 2019*
RELATED PCT APPLICATION NUMBER: *PCT/US20/25042*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/826,536*

Certified by

Andrei Iancu

Under Secretary of Commerce
for Intellectual Property
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Patent and Trademark Office

PTO/AIA/14 (02-18)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	35703-43263/US
	Application Number	
Title of Invention	SOLID-STATE FREQUENCY MODULATED CONTINIOUS WAVE LIDAR SYSTEM USING AN ARRAY OF COHERENT RECEIVERS EACH FED BY AN ACTIVELY SWITCHED ANTENNA ARRAY	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

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☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Amir		Hosseini	

Residence Information (Select One) ● US Residency Non US Residency Active US Military Service

City	State/Province	Country of Residence
San Jose	CA	US

Mailing Address of Inventor:

Address 1	OURS Technology Inc.
Address 2	4701 Patrick Henry Dr #18
City	Santa Clara
State/Province	CA
Postal Code	95054
Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Sen		Lin	

Residence Information (Select One) ◉ US Residency Non US Residency Active US Military Service

City	State/Province	Country of Residence
Mountain View	CA	US

Mailing Address of Inventor:

Address 1	OURS Technology Inc.
Address 2	4701 Patrick Henry Dr #18
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State/Province	CA
Postal Code	95054
Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

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☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	00758		
Email Address	ptoc@fenwick.com	Add Email	Remove Email

Application Information:

Title of the Invention	SOLID-STATE FREQUENCY MODULATED CONTINIOUS WAVE LIDAR SYSTEM USING AN ARRAY OF COHERENT RECEIVERS EACH FED BY AN ACTIVELY SWITCHED ANTENNA ARRAY		
Attorney Docket Number	35703-43263/US	**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	3	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

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Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Authorization or Opt-Out of Authorization to Permit Access:

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Clear

Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

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Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☐

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Address 1			
Address 2			
City		**State/Province**	
Country		Postal Code	
Phone Number		Fax Number	
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Address 2			
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Country i		Postal Code	
Phone Number		Fax Number	
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Signature:

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This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Michael W. Farn/			Date (YYYY-MM-DD)	2019-03-29
First Name	Michael W.	Last Name	Farn	Registration Number	41,015

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This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

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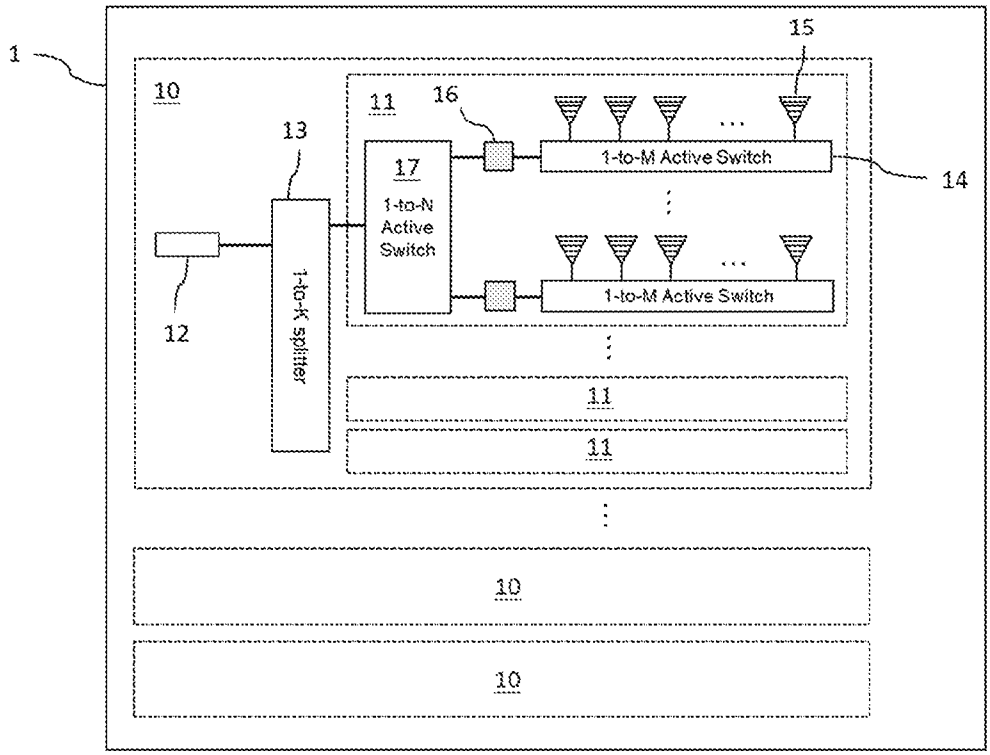

1
10
11
16
15
13
17
1-to-N Active Switch
1-to-M Active Switch
14
1-to-M Active Switch
12
1-to-K splitter
11
11
10
10

Figure 1

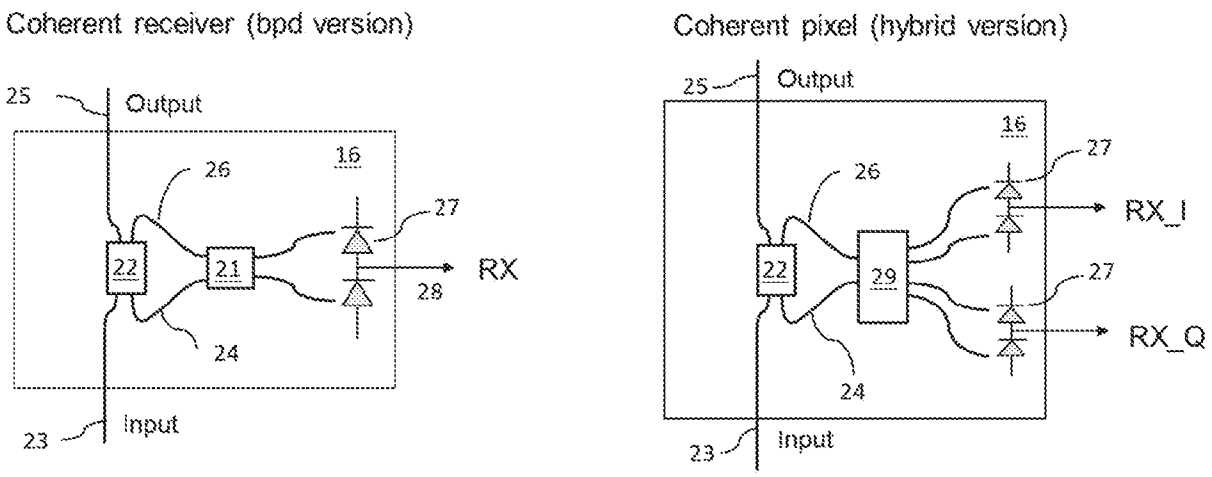


Figure 2

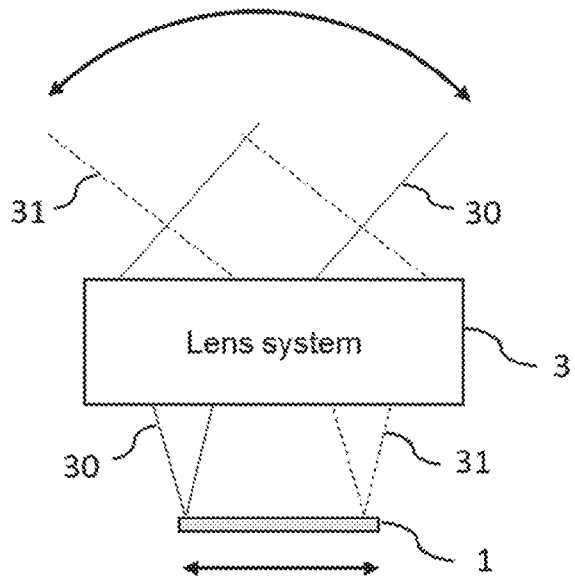
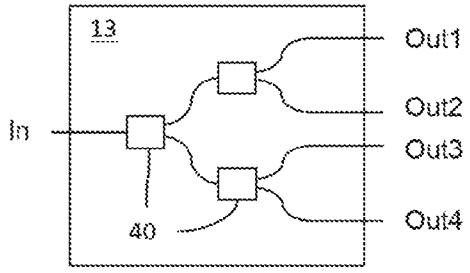


Figure 3

An example of 1-to-K splitter



An example of 1-to-M active switch network

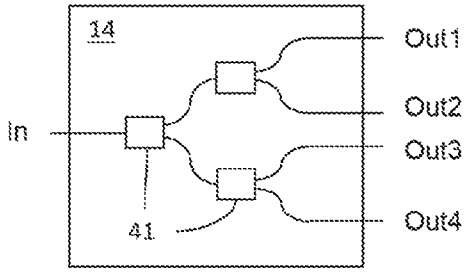


Figure 4

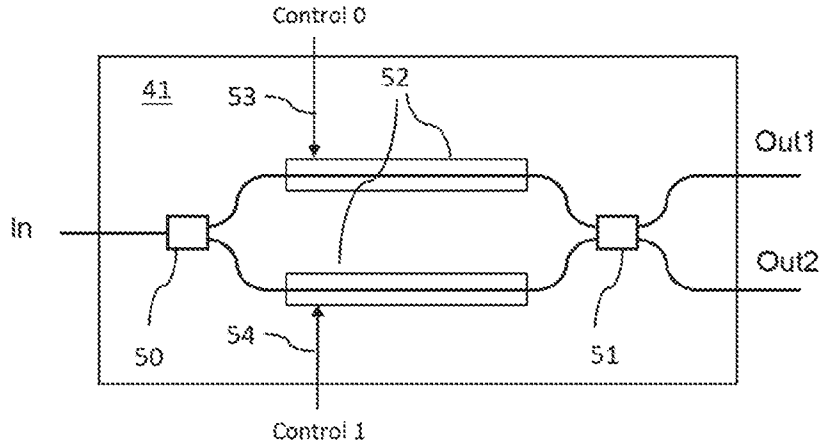


Figure 5

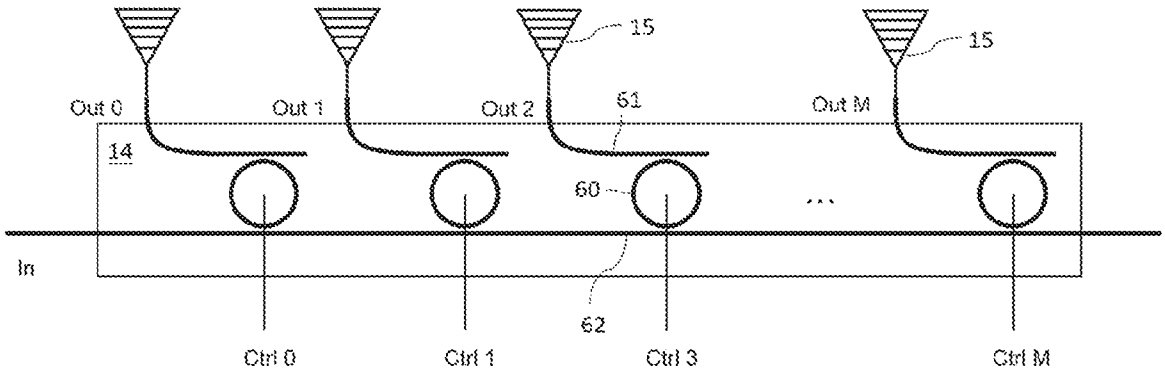


Figure 6

CLAIMS

What is claimed is:

1. A method comprising any process in any disclosure herein, performed by any component in any disclosure herein.

2. An apparatus comprising any component in any disclosure herein, configured to perform any process in any disclosure herein.

SOLID-STATE FREQUENCY MODULATED CONTINUOUS WAVE LIDAR SYSTEM USING AN ARRAY OF COHERENT RECEIVERS EACH FED BY AN ACTIVELY SWITCHED ANTENNA ARRAY

BACKGROUND OF THE INVENTION

[0001] The present invention is in the technical field of solid-state LIDAR.

[0002] Conventional LIDAR systems require mechanical moving parts to steer the laser beam. They are considered bulky, costly and unreliable for many applications, such as automotive and robotics.

[0003] Solid-state LIDARs overcome these issues by eliminating mechanically moving parts required to steer the optical beam for LIDAR operation. A Focal Plane Array (FPA), which maps the direction the incoming beam into the position of the focused spot size, and vice versa, can be used to realize solid-state beam steering, hence enabling solid-state LIDARs.

[0004] Frequency Modulated Continuous Wave (FMCW) lidars directly measure range and velocity of an object by directing a frequency modulated, calumniated light beam at the object. The light that is reflected from the object is combined with a tapped version of the beam. The optical signal reflected from the object is herein referred to as Signal and the tapped version is referred to as LO.

[0005] The frequency of the resulting beat tone is proportional to the distance of the object from the LIDAR system once corrected for the doppler shift that requires a second measurement. The two measurements, which may or may not be performed at the same time, provide both range and velocity information.

SUMMARY OF THE INVENTION

[0006] The present invention is a solid-state LIDAR system based on an FPA on chip. Parallel channels shoot beams at different directions at the same time. The measurement time is prolonged by a factor equal to the number of parallel channels thus Signal to Noise Ratio (SNR) is increased by a factor of K enabling long distance (>200m) detection range.

[0007] In the present invention a row of M actively switched optical antennas send Frequency Modulated (FM) signal out of the chip and receive the reflected signal, which is mixed with LO at a Coherent Receiver (CR).

[0008] The CR array and the antenna array form a two-dimensional array that enables two-dimensional optical beam steering.

BRIEF DESCRIPTION OF THE DRAWING

[0009] Figure 1 shows a schematic of the proposed System on Chip (SoC) design of the FPA chip, 1. The chip is divided into P subsets. Each subset, 10, consists of an optical I/O port, 12, a 1-to-K passive optical splitter, 13. Each of the 1-to-K optical splitter feeds a 1-to-N optical switch network that selects 1 out of N CRs, 16. Hence there are PxK parallel channels. An Optical switch network, 14, selects one out of the M antennas, 15, to send and receive Frequency Modulated (FM) light for ranging and detection. Each of the optical I/Os is fed by a frequency modulated laser light provided by a laser array. Hence, at any given time, one out of the NxM antennas in 11 is selected for operation.

[0010] Figure 2 shows two versions of CR. Light from the switched network, 14, is provided to the optical input of the CR, 23. A 2x2, bi-directional splitter, 22, splits the light into two outputs 25 and 26. The optical power 25 is sent out of the chip using one of the M actively switched antenna at a time. The antenna is reciprocal and collects the reflected beam from the object and

send it back to the CR through the same line 25. The bi-directional 2x2 splitter splits the returned signal between ports 24 and 23. The returned Signal, 24 and LO 26, are mixed either using a balanced 2x2, 21 in the version on the left or using an optical hybrid, 29, in the version on the right. Finally, a pair of Photo-Diodes (PDs), 27, in version on the left and 4 PDs in the version on right convert the optical signal into electrical signal for beat tone detection. We refer to the version on the left as the Balanced Photo Diode (BPD) version and the version on the right is the hybrid version. The hybrid version provides in-phase and quadrature outputs, which are used to determine the sign of the velocity from the doppler shift in the measured beat tone.

[0011] Figure 3 illustrates optical beam steering using FPA. The photonic chip,1, is placed at the focal distance of a lens system, 3, that maps the physical location of each CPs, in to a unique direction. The optical antenna on the left-most CP, 30, sends and receives light along the solid line, while the right-most CP, 31, sends and receives light along the dashed line. All CPs in between steer the light into a direction in between these 2 lines and hence, a discrete optical beam scanning is achieved.

[0012] Figure 4 shows examples of 1-to-K passive optical switch splitter, 13, and 1-to-M active optical switch network, 14. The passive network here consists of a tree of 2x2 optical splitters, 40, whereas in the active network, each 2x2 splitter is replaced by an optical switch, 41. The 1xN active switch network, 17, is identical to 14 in architecture and control but M and N are generally not the same.

[0013] An optical switch used in the active switch network is depicted in Figure 5. A 3dB optical splitter, 50, feeds two optical phase shifters, 52, which tune the phase of each arm using control signals 53, and 54. The optical signal in the two arms are combined using an optical 2x2.

Depending on the control signals, constructive (deconstructive) interference occurs at Out 1 (Out 2) or vice versa and hence the light is switched between the two outputs.

[0014] The actively switched antenna array, 14, can also be implemented using an entirely different architecture as depicted in Figure 6, in which, an array of Micro Ring Resonators, MRRs, 60, select one of the M antennas through which the FM Signal is sent and received.

Electronic Acknowledgement Receipt

EFS ID:	35565852
Application Number:	62826536
International Application Number:	
Confirmation Number:	3361
Title of Invention:	SOLID-STATE FREQUENCY MODULATED CONTINIOUS WAVE LIDAR SYSTEM USING AN ARRAY OF COHERENT RECEIVERS EACH FED BY AN ACTIVELY SWITCHED ANTENNA ARRAY
First Named Inventor/Applicant Name:	Amir Hosseini
Customer Number:	758
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Warnings:					
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2	Drawings-other than black and white line drawings	43263_US_DRAWINGS.pdf	489696 593c8595636f7a0ac6cf3bdb792b8fda4f787aa6	no	3
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