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LOUDSPEAKER WITH INTEGRATED IMAGE-CAPTURING MODULE

Abstract

An acoustic system (and method) for a loudspeaker includes a bottom plate; a pole-piece extending from a surface of the bottom plate. The pole-piece may include a through-bore along a central axis. A magnet at least partially surrounds. A diaphragm extends above the top surface of the pole-piece and forming a conical envelope above the top surface of the pole-piece. The diaphragm may include a central opening exposing at least a portion of the top surface of the pole-piece through a central channel. An image-capture module is disposed on the top surface of the pole-piece and extends through the central channel and at least partially into the conical envelope of the diaphragm such that at least a lens associated with a camera of the image-capture module is located within the conical envelope but outside of the central channel.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application claims priority of U.S. Provisional Application No. 63/551,877 filed on Feb. 9, 2024 under 35 U.S.C. § 119(e), the entire contents of all of which are hereby incorporated by reference.

TECHNICAL FIELD
[0002] The present application generally relates to loudspeakers, and in particular, to loudspeakers with an integrated image-capturing module.
BACKGROUND
[0003] In addition to entertainment and recreational purposes, “content creation” or “twitch streaming” is gaining popularity as a strong tool for business analytics, freelancing and entrepreneurship, leadership and management skill development, marketing, among other things. Currently, a content creator relies on a variety of equipment for high quality audio and video capturing and processing, rendering the experience cumbersome, expensive, inefficient, and occasionally discouraging.
[0004] A content creator may benefit from tools that are portable, versatile, inexpensive, and generate high-quality audio-visual effects to highlight their work. Although high-quality audio-visual reproduction equipment may be suitable for planned events such as conferences, seminars, concerts, etc., commercially available equipment may be either expensive, or cumbersome, or both. On the other hand, while multi-functional hand-held devices such as smartphones offer portability, the audio-visual quality of recorded information may not be desirable. Additionally, it may be difficult to replace or repair hardware, e.g., camera lens, of a smartphone, rendering the device non-versatile. Therefore, it is desirable to integrate audio systems with image-capturing capabilities to enhance the user experience, while keeping costs low and generating high-quality audio and image outputs.
SUMMARY
[0005] Embodiments consistent with the present disclosure generally describe acoustic systems for an audio-output device, and the systems include an integrated image-capturing module and methods of operating and providing the same.
[0006] Some embodiments of the present disclosure are directed to an electroacoustic transducer system for a loudspeaker. The electroacoustic transducer system may include a bottom plate and a pole-piece extending from a surface of the bottom plate. The pole-piece may include a through-bore along a central axis, and the pole-piece may have a top surface on an end of the pole-piece distally located relative to the bottom plate. The electroacoustic transducer system may further include a magnet at least partially surrounding the pole-piece and a diaphragm extending above the top surface of the pole-piece and forming a conical envelope above the top surface of the pole-piece. The diaphragm may include a central opening exposing at least a portion of the top surface of the pole-piece through a central channel. The electroacoustic transducer system may further include an image-capture module disposed on the top surface of the pole-piece and extending through the central channel and at least partially into the conical envelope of the diaphragm such that at least a lens associated with a camera of the image-capture module is located within the conical envelope but outside of the central channel.
[0007] Some embodiments of the present disclosure are directed to an acoustic system for a passive radiator. The system may include a diaphragm. The diaphragm includes a central opening extends and forms a conical envelope. The system may further include an image-capture module extending through the central opening and at least partially into the conical envelope of the diaphragm such

that at least a lens associated with a camera of the image-capture module is located within the conical envelope but above of the central opening.
[0008] This invention helps integrate both a speaker and camera into a single concentric surface area, reducing total needed surface area to make the camera less noticeable and blend in with the surroundings better. It also allows better and louder sound with the bigger moving diaphragm. It can be used for a portable content creation device or IoT security devices, like the Ring or Nest doorbell cams.

Description

BRIEF DESCRIPTION OF DRAWING(S)
[0009] FIG. **1**A illustrates a cross-section view of an exemplary electroacoustic transducer system including an image-capturing module, consistent with some embodiments of the present disclosure.
[0010] FIG. **1**B illustrates a cross-section view of an exemplary passive radiator system including an image-capturing module, consistent with some embodiment of the present disclosure.
[0011] FIG. **1**C illustrates a cross-section view of another embodiment of passive radiator system including an image-capturing module, consistent with some embodiment of the present disclosure.
[0012] FIG. **2**A illustrates an exemplary image-capture module, consistent with some embodiments of the present disclosure.
[0013] FIG. **2**B illustrates a partial cross-section view of an exemplary electroacoustic transducer system including a dust seal, consistent with some embodiments of the present disclosure.
[0014] FIG. **3** illustrated an exemplary image-capture module, consistent with some embodiment of the present disclosure.
DETAILED DESCRIPTION
[0015] The following detailed description refers to the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the following description to refer to the same or similar parts. While several illustrative embodiments are described herein, modifications, adaptations and other implementations are possible. For example, substitutions, additions or modifications may be made to the components illustrated in the drawings, and the illustrative methods described herein may be modified by substituting, reordering, removing, or adding steps to the disclosed methods. Accordingly, the following detailed description is not limited to the disclosed embodiments and examples. Instead, the proper scope is defined by the appended claims.
[0016] Some aspects of this disclosure may relate to systems and methods associated with an electroacoustic transducer system for a loudspeaker. An electroacoustic transducer, in this context, may refer to a device that converts electrical energy into acoustic energy or sound waves having a frequency typically in the range of 10 Hz to 40 KHz. In some embodiments, although not discussed herein, the electroacoustic transducer system may further comprise components and associated circuitry to convert an input acoustic signal into an electrical signal, and re-convert the electrical signal into an output acoustic signal. The output acoustic signal may comprise a modified audio signal with reference to the input acoustic signal. A loudspeaker may include a pressure generating output device used to amplify or modify an input signal using a sound transducer system such as an electroacoustic transducer system. The input signal may comprise an audio signal, an electrical signal, or a combination thereof. It is appreciated that although this application discusses a loudspeaker, other audio output devices may include but not limited to, woofers, sub-woofers, tweeter horns, etc.
[0017] FIG. **1**A illustrates an exemplary electroacoustic transducer system **100** for a dynamic moving-coil loudspeaker, consistent with disclosed embodiments. The electroacoustic transducer system **100**, having a central axis **102**, may comprise a diaphragm **104** comprising a central opening **126**, a spider **106**, a voice coil **108**, a former **110**, a through-bore **112** in a pole-piece **114**, a

bottom plate **116**, a magnet **118**, a top plate **120**, a surround **122** connecting the diaphragm **104** with a basket **124**, and an image-capture module **130**. The central axis **102**, shown in FIG. **1**A for illustrative purposes, may represent an axis of rotational symmetry. The electroacoustic transducer system **100** may include more or fewer components, as appropriate.

[0018] The electroacoustic transducer system **100** comprises a bottom plate **116**. In some embodiments, the bottom plate **116** may include a plate, a disc, a ring, or in the broadest terms, a structure configured to provide support, at least to the pole-piece **114**, or to the magnet **118** (including top plate **120**). The magnet **118** and top plate **120** may be substantially coaxial with the pole-piece **114**. Additionally, the magnet **118** and the top plate **120** may at least partially surround the pole-piece **114**. The bottom plate **116** may be made from ferromagnetic materials including, but not limited to, iron, cobalt, nickel, or alloys thereof. Alternatively, the bottom plate **116** may be made from non-magnetic metals, alloys, composites, or other materials suitable for providing structural support.

[0019] The electroacoustic transducer system **100** may further comprise a pole-piece **114** extending from a surface of bottom plate **116**. In some embodiments, the pole-piece **114** may be coupled to or integrated with the bottom plate **116** such that the bottom plate **116** forms a continuous extension of the pole-piece **114**. In the context of this disclosure, the term “coupled” may indicate that two or more elements can be directly coupled to one another or coupled to one another through one or more intermediate elements. The pole-piece **114** may be coupled to the bottom plate **116** such that a top surface on one end of the pole-piece **114** distally located relative to bottom plate **116** is partly exposed and the other end is coupled to the bottom plate **116**. In some embodiments, the bottom plate **116** and the pole-piece **114** may form a seamless structure without any joints or discontinuities.

[0020] In some disclosed embodiments, the pole-piece **114** may include a through-bore **112** extending along the central axis **102**. The through-bore **112** of the pole-piece **114** may be substantially aligned with the central axis **102**. The through-bore **112** may comprise a continuous hole extending from the top surface of one end of pole-piece **114** through the bottom plate **116**. The through-bore **112** may have a circular, an elliptical cross-section, a rectangular cross-section, a triangular cross-section, a non-circular cross-section, or any combination thereof. In some embodiments, the through-bore **112** may have a cylindrical shape, a conical shape, a cubical shape, or any combination thereof.

[0021] The electroacoustic transducer system **100** may comprise a diaphragm **104** extending above the top surface of the pole-piece **114** (e.g., when viewed from the side as in FIG. **1**A). In some embodiments, the diaphragm **104** may form a conical envelope extending above the top surface of the pole-piece **114**, as shown in FIG. **1**A. The diaphragm **104** may be made from any material for use in sound reproduction applications. For example, the diaphragm may include materials comprising fabric, paper, plastic, lightweight metal, or various other materials. The diaphragm **104** may be fixedly attached to an outer surface of the basket **124** via a flexible surround **122**. The diaphragm **104** may be truncated along a truncation plane to form a “truncated cone.” The truncation plane may be substantially perpendicular to the central axis **102** and may truncate a region proximal to and including the apex of the conical diaphragm **104**, creating a central opening **126** in the diaphragm **104**. In some embodiments, the central opening **126** may expose at least a portion of the top surface of pole-piece **114** through a central channel **128**. The diaphragm **104** and central channel **128** may be coaxially arranged relative to pole-piece **114**.

[0022] The electroacoustic transducer system **100** may further include a voice coil assembly comprising, e.g., a voice coil **108** wrapped around a former **110**. The voice coil **108** may comprise an electrical conductor such as, for example, one or more metal wires wound around an external surface of the former **110**. Electrical currents passing through the voice coil **108** produce corresponding electromagnetic fields which may interact with the magnetic field of the magnet **118** to cause controlled movement of the voice coil **108** and, therefore, the diaphragm **104** in order to reproduce sounds. The former **110** may comprise a rigid cylinder made of a material comprising, but not limited to, paper, cardboard, or the like, around which the voice coil **108** is wrapped. In some embodiments, as illustrated in FIG. **1**A, the former **110** may be attached to the diaphragm **104** at the truncated end of the diaphragm **104**. The spider **106** may comprise a flexible, corrugated support that secures the voice coil **108** in place while allowing the voice coil **108** to move longitudinally along the central axis **102** in response to the polarity and magnitude of electrical currents provided to the voice coil **108**.

[0023] The electroacoustic transducer system **100** may further comprise an image-capture module **130** disposed on the top surface of the pole-piece **114**. In some embodiments, the image-capture module **130** may be attached to the pole-piece **114** using a coupling mechanism including mechanical coupling, or thermal coupling, adhesive coupling, or any other suitable means. As shown in FIG. **1**A, the image-capture module **130** may be attached to the pole-piece **114** such that at least a portion of the image-capture module **130** extends below the top surface of the pole-piece **114** in order to seat the image-capture module **130** within a recess of the top surface of the pole-piece **114**. In some embodiments, the image-capture module **130** may be disposed coaxially with the pole-piece **114** and may be attached to or disposed on the top surface of the pole-piece **114** without including a recess to accept a base of the image-capture module **130**.

[0024] The central channel **128** may refer to a cylindrical space or region formed within the former **110** and the truncation plane **105** of the diaphragm **104**. The conical envelope of the diaphragm **104** may refer to the conical space formed between the truncation plane **105** and a base plane **107** of the diaphragm **104**. As shown in FIG. **1**A, the image-capture module **130** may be at least partially disposed within the central channel **128**. In some embodiments, the image-capture module **130** may extend through the central channel **128** and at least partially into the conical envelope of the diaphragm **104**. Protrusion of the image-capture module **130** into the conical envelope of the diaphragm **104** extending through the central channel **128** may provide a larger field-of-view to capture visual information from a wider area.

[0025] FIG. **1**B illustrates an exemplary acoustic system **300** for a passive radiator, consistent with disclosed embodiments. The system **300** has a central axis **302** and may comprise a diaphragm **304** comprising a central opening **326**, a surround **322** connecting the diaphragm **304** with a basket **324**, a support **314** and an image-capture module **330**. The central axis **302**, shown in FIG. **1**B for illustrative purposes, may represent an axis of rotational symmetry. The system **300** may include more or fewer components, as appropriate.

[0026] The system **300** may comprise diaphragm **304** extending above the central opening **326** (e.g., when viewed from the side as in FIG. **1**B). In some embodiments, the diaphragm **304** may form a conical envelope extending above the central opening **326**, as shown in FIG. **1**B. The diaphragm **304** may be made from any material for use in sound reproduction applications. For example, the diaphragm may include materials comprising fabric, paper, plastic, lightweight metal, or various other materials. The diaphragm **304** may be fixedly attached to an outer surface of basket **324** via a flexible surround **322**. The diaphragm **304** may be truncated along a truncation plane **305** to form a “truncated cone.” The truncation plane may be substantially perpendicular to the central axis **302** and may truncate a region proximal to and including the apex of the conical diaphragm **304**, creating a central opening **326** in diaphragm **304**.

[0027] The conical envelope of the diaphragm **304** may refer to the conical space formed between the truncation plane **305** and a base plane **307** of the diaphragm **304**. In some embodiments, the image-capture module may extend through the central opening **326** and at least partially into the conical envelope of the diaphragm **304**. A protrusion of the image-capture module **330** into the conical envelope may provide a larger field-of-view to capture visual information from a wider area.

[0028] The system **300** may further comprise the image-capture module **330** disposed on the support **314**. In some embodiments, the image-capture module **330** may be attached to the support

314 using a coupling mechanism including mechanical coupling, or thermal coupling, adhesive coupling, or any other suitable means. As shown in FIG. **1**B, the image-capture module **330** may be attached to the support **314** such that at least a portion of the image-capture module **330** extends below the top surface of the support **314** in order to seat the image-capture module **330** within a recess of the support **314**. In some embodiments, the image-capture module **330** may be disposed coaxially with the support **314** and may be attached to or disposed on the top surface of the support **314** without including a recess to accept a base of the image-capture module **330**.

[0029] FIG. **1**C illustrates another exemplary acoustic system **300′** for a passive radiator, consistent with disclosed embodiments. The system **300′** has a central axis **302′** and may comprise a diaphragm **304′** comprising a central opening **326′**, a through-bore **312** in a support **314′**, a surround **322′** connecting the diaphragm **304′** with a basket **324′**, and an image-capture module **330′**. In some embodiments, the central opening **326′** may expose at least a portion of the top surface of the support **314′** through a central channel **328**. The diaphragm **304′** and the central channel **328** may be coaxially arranged relative to the support **314′**. The central axis **302′**, shown in FIG. **1**C for illustrative purposes, may represent an axis of rotational symmetry. The acoustic system **300′** may include more or fewer components, as appropriate.

[0030] In some embodiments, the diaphragm **304′** may form a conical envelope extending above the central opening **326′**, as shown in FIG. **1**C. The conical envelope of the diaphragm **304′** may refer to the conical space formed between a truncation plane **305′** and a base plane **307′** of the diaphragm **304′**. In some embodiments, the image-capture module **330′** may extend through the central opening **326′** and at least partially into the conical envelope of the diaphragm **304′**. A protrusion of the image-capture module **330′** into the conical envelope may provide a larger field-of-view to capture visual information from a wider area.

[0031] FIG. **2**A provides a close-up view of image-capture module **130**. The image-capture module **130** may be configured to capture still photographs, videos, or other visual information. The image-capture module **130** may comprise a lens **234** associated with a camera **235** disposed on a spacer element **236**, and an electrical connector **132**. The lens **234** may be disposed on a top surface of the camera **235** distal from the spacer element **236**. In some disclosed embodiments, the image-capture module **130** may be disposed on a top surface of the pole-piece **114** (as shown in FIG. **1**A) such that at least the lens **234** associated with the camera **235** is located within the conical envelope but outside the central channel **128**. In some embodiments, the camera **235** may be positioned along the central axis **102** such that the camera **235** associated with the image-capture module **130** resides fully within the conical envelope.

[0032] FIG. **3** provides a close-up view of image-capture module **330**. The image-capture module **330** may be configured to capture still photographs, videos, or other visual information. The image-capture module **330** may comprise a lens **334** associated with a camera **335** disposed on a spacer element **336**, and an electrical connector **332**. The lens **334** may be disposed on a top surface of the camera **335** distal from the spacer element **336**. In some disclosed embodiments, the image-capture module **330** may be disposed on the support **314** such that at least the lens **334** associated with the camera **335** is located within the conical envelope but outside the central opening **326**. In some embodiments, the camera **335** may be positioned along the central axis **302** such that the camera **335** associated with the image-capture module **330** resides fully within the conical envelope.

[0033] The field-of-view (FOV) associated with a camera (e.g., camera **235**) refers to the maximum area that the camera can image, and may be determined based on the focal length of the lens and the size of the sensor. Angular field-of-view (AFOV) refers to the angle between any light captured at the optical axis, and any light captured at the edge of the lens. For a fixed sensor size, increasing the focal length of the lens may reduce the AFOV, and reducing the focal length of the lens may increase the AFOV, and therefore increase the FOV as well.

[0034] In some disclosed embodiments, an angular field of view **150** (shown in FIG. **1**A) associated with camera **235** may be greater than an angle associated with a vertex of the conical envelope of diaphragm **104**. Positioning the camera **235** on the spacer element **236** such that either the lens **234** or the camera **235** including the lens **234** is located fully within the conical envelope and protruding from the central channel **128** may offer several potential advantages. For example, the angular field-of-view (AFOV) associated with the camera **235** comprising the lens **234** protruding above the truncation plane into the conical envelope of the diaphragm **104** may be larger in comparison to the AFOV associated with a camera lens located below the truncation plane. Such a configuration may allow a user to capture images representative of larger areas of an environment relative to cameras with more limited AFOVs. In some embodiments, the angular field-of-view associated with the camera **235** is at least 90°. In some embodiments, the angular field-of-view associated with the camera **235** is at least 135°.

[0035] In the context of this disclosure, the term “resolution” of a camera indicates pixel resolution, considered equivalent to pixel count within a specified area of an image. For example, an image comprising 2048 pixels in width and 1536 pixels in height has a total of 3,145,728 pixels or 3.1 megapixels. In some embodiments, the camera **235** may have a resolution of at least 1.3 megapixels. It will be appreciated that the pixel resolution of a camera may be determined by the number of pixels available in an image sensor and that higher pixel resolution may result in better image quality.

[0036] The image-capture module **130** may comprise the spacer element **236** configured to connect the camera **235** with the top surface of the pole piece **114**. In some embodiments, one end of the spacer element **236** may be attached to camera **235**, and the other end may be attached to the pole-piece **114**, forming a connection between the camera **235** and the pole-piece **114**, as illustrated in FIG. **2**. In some embodiments, the camera **235** may be removably attached to the spacer element **236** through an attachment mechanism such as a mechanical coupling, for example. Such an attachment mechanism may offer several advantages. For example, the attachment mechanism may allow a user to easily and quickly replace a camera-lens assembly based on a desired output or application. A top end of the spacer element **236** may be configured to receive and/or releasably secure the camera **235**, and a bottom end may be configured to attach to the pole-piece **114** (e.g., fixedly or releasably).

[0037] In some embodiments, the length of the spacer element **236** may be adjustable to enable selective positioning of the camera **235** along the central axis **102**. In some disclosed embodiments, the spacer element **236** may have a length greater than a depth of the central channel **128**. The length of the spacer element **236** may be adjustable, at least based on a desired AFOV. As an example, for a given camera-lens assembly, a longer spacer element **236** may protrude farther into the conical envelope of the diaphragm **104**, thus providing a larger AFOV compared to a shorter spacer element **236**. In some embodiments, the position of the spacer element **236** may be adjustable to adjust the position of the camera **235** attached to the spacer element **236**, thereby adjusting the AFOV of the camera **235**.

[0038] The length of the spacer element **236** may be extendable along the central axis **102**. In some embodiments, a minimum contracted length of the spacer element **236** may be substantially equal to or greater than the depth of the central channel **128**. Alternatively, in some embodiments, the minimum contracted length may be less than the depth of the central channel **128**, but the fully extended length may be greater than the depth of the central channel **128**.

[0039] The image-capture module **130** may further include control circuitry **238** configured to control operation of the camera **235**. The control circuitry **238** may comprise one or more electronic circuit components including, but not limited to, resistors, capacitors, inductors, power source, power management components, timers, or the like. Controlling operation of the camera **235** may include, for example, activation and deactivation of the camera **235** by managing power supply. The control circuitry **238** may be configured to perform other suitable functions as well. In some embodiments, the control circuitry may comprise an integrated circuit, a microprocessor, a processor, a data storage mechanism, a data transfer mechanism, or other relevant components.

[0040] In some disclosed embodiments, the spacer element **236** may be placed coaxially relative to the pole-piece **114**. The spacer element **236** may be cylindrical, cubical, conical, or other shape. In some embodiments, the spacer element **236** and the the pole-piece **114** are cylindrical, and the bottom end of the spacer element **236** has one of male threads and female threads, and the top end of the pole-piece **114** has a cylindrical cavity having the other of the male threads and the female threads corresponding to one of the male threads and the female threads of the spacer element **236**. That is, if the bottom end of the spacer element **236** has the male threads, the cavity of the pole-piece **114** has the female threads; if the bottom end of the spacer element **236** has the female threads, the cavity of the pole-piece **114** has the male threads. The radius of the cavity is greater than the radius of the spacer element **236** so that the spacer element **236** can be placed in the cavity and be fixed by the threads. In some embodiments, the spacer element **236** and the pole-piece **114** are cylindrical, and the bottom end of the spacer element **236** has a cylindrical cavity having one of male threads and female threads and the top end of the pole-piece **114** has the other of the male threads and the female threads corresponding the threads of the cavity of the spacer element **236**. That is, if the cavity of the spacer element **236** has the male threads, the pole-piece **114** has the female threads; if the cavity of the spacer element **236** has the female threads, the pole-piece **114** has the male threads. The radius of the cavity is greater than the radius of the area of the top end of the pole-piece **114** so that the top end of the pole-piece **114** can protrude into the cavity and be fixed by the threads. In some embodiments, the control circuitry **238** may be housed within the spacer element **236**. The control circuitry **238** may be located outside the spacer element **236** but within the electroacoustic transducer system **100**, or at a remote location.
[0041] The image-capture module **130** may further comprise an electrical connector **132**. In some cases, the electrical connector **132** may provide power to the image-capture module **130** and/or to one or more components of the control circuitry **238**. The electrical connector **132** may also be configured to enable communication between an external controller **260** and the control circuitry **238** housed within the spacer element **236**. Some examples of communication between the external controller **260** and the control circuitry **238** may include, but are not limited to, shutter release signals, switching in and out of power-save mode, auto-focus, feature identification, etc. Alternatively, in some embodiments, the electrical connector **132** may be part of the electroacoustic transducer system **100**. The electrical connector **132** may comprise one or more of a power cable, a signal cable, a data transfer cable, or an electronic communication cable suitable for transferring power and/or electrical signals between the external controller **260** and/or various power sources and the control circuitry **238** and/or the components of the image-capture module **130**. The spacer element **236** may include a central opening in the bottom surface configured to allow passage of the electrical connector **132** therethrough. In some embodiments, the opening may be coaxial with the pole-piece **114**. In some embodiments, at least a portion of electrical connector **132** is disposed within the through-bore **112** of the pole-piece **114**, as illustrated in FIGS. **1**A and **2**A.
[0042] The external controller **260** may comprise a computer, a processor, a microprocessor, an integrated circuit, or circuitry configured to communicate with the control circuitry **238**. In some embodiments, the external controller **260** may be associated with a graphic user interface (GUI) such as an interactive display, touch screen, input-output apparatus, or other means of interaction between a user and the electroacoustic transducer system **100**. The external controller **260** may further comprise a data storage mechanism including, but not limited to, a database, a server, or a memory, configured to receive, store, or process data from the image-capture module **130**, for example. In some embodiments, the external controller **260** may be remotely controlled using a wireless communication means.
[0043] By way of example, a user may provide an input command, remotely, using the GUI interface of the external controller **260**, the input command instructing the control circuitry **238** to activate the camera **235** by supplying power through an activation circuit. In another example, the user may want to capture some visual information in the field-of-view of the camera **235**. In such a

case, the user may provide an appropriate command to the external controller **260** to instruct the control circuitry **238** to initiate capturing of an image or a sequence of images in a video format. In some embodiments, the captured information may be transferred from a temporary data storage medium of the control circuitry **238** to a data storage component of the external controller **260** using the electrical connector **132** (e.g., a data cable).

[0044] In some disclosed embodiments, as shown in FIG. **3**, the image-capture module **330** may further include a control circuitry **338** configured to control operation of the camera **335**. The control circuitry **338** may comprise one or more electronic circuit components including, but not limited to, resistors, capacitors, inductors, power source, power management components, timers, or the like. Controlling operation of the camera **335** may include, for example, activation and deactivation of the camera **335** by a managing power supply. The control circuitry **338** may be configured to perform other suitable functions as well. In some embodiments, the control circuitry may comprise an integrated circuit, a microprocessor, a processor, a data storage mechanism, a data transfer mechanism, or other relevant components.

[0045] The image-capture module **330** may further comprise an electrical connector **332**. In some cases, the electrical connector **332** may provide power to the image-capture module **330** and/or to one or more components of the control circuitry **338**. The electrical connector **332** may also be configured to enable communication between an external controller **360** and the control circuitry **338** housed within the spacer element **336**. Some examples of communication between the external controller **360** and the control circuitry **338** may include, but are not limited to, shutter release signals, switching in and out of power-save mode, auto-focus, feature identification, etc. The electrical connector **332** may comprise one or more of a power cable, a signal cable, a data transfer cable, or an electronic communication cable suitable for transferring power and/or electrical signals between the external controller **360** and/or various power sources and the control circuitry **338** and/or components of the image-capture module **330**. The spacer element **336** may include a central opening in the bottom surface configured to allow passage of the electrical connector **332** therethrough.

[0046] The external controller **360** may comprise a computer, a processor, a microprocessor, an integrated circuit, or circuitry configured to communicate with control circuitry **338**. In some embodiments, the external controller **260** may be associated with a graphic user interface (GUI) such as an interactive display, touch screen, input-output apparatus, or other means of interaction between a user and the acoustic system **300**. The external controller **360** may further comprise a data storage mechanism including, but not limited to, a database, a server, or a memory, configured to receive, store, or process data from the image-capture module **330**, for example. In some embodiments, the external controller **360** may be remotely controlled using a wireless communication means.

[0047] In some disclosed embodiments, the electroacoustic transducer system **100** may further include a dust seal **240** configured to impede particulate entry into the central channel **128**, as shown in FIG. **2**B. Entry of dust particles, debris, particulates, or the like into the central channel **128** may hinder the movement of the voice coil **108** along the central axis **102**, thereby causing variation in tonal characteristics of output audio signals, and resultantly deterioration of sound quality. The dust seal **240** may be configured to minimize the occurrence of sound quality deterioration by impeding entry of undesirable particulates into the central channel **128**. The dust seal **240** may comprise a mesh, a screen, a filter, a paper, or any other material appropriate for preventing dust particles from falling into the central channel **128**. The dust seal **240** may comprise at least one transparent dust cover such that the dust seal **240** may not block or absorb light to be captured by the camera **235**. In some embodiments, the dust seal **240** may be radially fastened to an inner surface of the diaphragm **104**. Although the dust seal **240** is shown as being disposed substantially perpendicular to the central axis **102**, a person of ordinary skill in the art would appreciate that other profiles of the dust seal **240** such as, for example, dome, semi-dome, conical, may be used, making the radius as small as possible without interfering with the camera module.

Claims

1. An acoustic system, comprising: a support having a top surface and a through-bore along a central axis of the support; a diaphragm extending and forming a conical envelop, and including a central opening; and an image-capture module, including a camera having a lens, disposed on the top surface of the support and extending through the central opening and at least partially into the conical envelope of the diaphragm such that at least the lens is located within and above the conical envelope.
2. The system of claim 1, wherein the camera of the image-capture module resides fully within the conical envelope formed by the diaphragm.
3. The system of claim 1, wherein an angular field of view associated with the camera is greater than an angle associated with a vertex of the conical envelope, and wherein the camera has a resolution of at least 1.3 megapixels.
4. The system of claim 3, wherein the angular field of view associated with the camera is at least 90°.
5. The system of claim 3, wherein the angular field of view associated with the camera is at least 135°.
6. The system of claim 1, wherein the image-capture module further comprises: a control circuitry configured to control operation of the camera; and a spacer element configured to connect the camera with the top surface of the support.
7. The system of claim 6, wherein the control circuitry is housed within the spacer element connecting the image-capture module to the top surface of the support.
8. The system of claim 7, further comprising an electrical connector configured to enable communication between an external controller and the control circuitry.
9. The system of claim 8, wherein the electrical connector comprises one or more of a power cable, a signal cable, a data transfer cable, or an electronic communication cable.
10. The system of claim 8, wherein at least a portion of the electrical connector is disposed within the through-bore of the support.
11. The system of claim 7, wherein the camera is removably attached to the spacer element.
12. The system of claim 1, further comprising one or more dust seals configured to impede particulate entry into the central opening.
13. The system of claim 12, wherein the one or more dust seals are radially fastened to an inner surface of the diaphragm.
14. The system of claim 12, wherein the one or more dust seals comprise at least one transparent dust cover.
15. The system of claim 1 further comprising: a bottom plate; and a magnet, wherein the support is a pole piece extending from a surface of the bottom plate, the magnet at least partially surrounds the pole-piece, the pole-piece has a top surface on an end of the pole-piece distally located relative to the bottom plate, and wherein the central opening of the diaphragm exposes at least a portion of the top surface of the pole-piece through a central channel.
16. The system of claim 15, wherein the spacer element and the pole-piece are cylindrical, the bottom end of the spacer element has one of male threads and female threads, the top end of the pole-piece has a cylindrical cavity having the other of the male threads and the female threads corresponding to one of the male threads and the female threads of the spacer element, and wherein a radius of the cavity is greater than a radius of the spacer element so that the spacer element can be placed in the cavity and be fixed by the threads.
17. The system of claim 15, wherein the spacer element and the pole-piece are cylindrical, the

bottom end of the spacer element has a cylindrical cavity having one of male threads and female threads, the top end of the pole-piece has the other of the male threads and the female threads corresponding to one of the male threads and the female threads of the spacer element, and wherein a radius of the cavity is greater than a radius of an area of the top end of the pole-piece so that the top end of the pole-piece can protrude into the cavity and be fixed by the threads.

18. The system of claim 15, wherein the spacer element has a length greater than a depth of the central channel.