SUMMARY

[0006] The innovations described in the claims each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of the claims, some prominent features of this disclosure will now be briefly described.

[0006a] In an aspect, the present disclosure refers to an acoustic wave device comprising: a piezoelectric layer; and an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bent section arranged to create a curvature in an acoustic aperture of the acoustic wave device to suppress a transverse spurious mode of the acoustic wave device, the interdigital transducer electrode including a bus bar and fingers in the bent section extending from the bus bar, the fingers having substantially the same length throughout the bent section.

[0006b] In another aspect, the present disclosure refers to an acoustic wave device comprising: a piezoelectric layer; and an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bus bar having an arcuate section and fingers extending from at least the arcuate section of the bus bar, the fingers having substantially the same length throughout the arcuate section, and the acoustic wave device having a curved acoustic aperture configured to suppress a transverse spurious mode of the acoustic wave device.

[0006c] In another aspect, the present disclosure refers to an acoustic wave filter comprising: an acoustic wave resonator including a piezoelectric layer and an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bus bar with an arcuate section and fingers extending from at least the arcuate section of the bus bar, the fingers having substantially the same length throughout the arcuate section, and the acoustic wave resonator having a curved acoustic aperture configured to suppress a transverse spurious mode; and a plurality of additional acoustic wave resonators, the acoustic wave resonator and the additional acoustic wave resonators are together configured to filter a radio frequency signal.

[0007] One example of this disclosure is an acoustic wave device that includes a piezoelectric layer and an interdigital transducer electrode on the piezoelectric layer. The interdigital transducer electrode includes a bent section arranged to create a curvature in a waveguide of the acoustic wave device to suppress a transverse spurious mode of the acoustic wave device.

[0008] The bent section can have a bend angle in a range from 1° to 20°. In some of these instances, the bent section can have a bend angle in a range from 10° to 20°. The acoustic wave device can further include a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave device.

[0009] The acoustic wave device can include a temperature compensation layer over the interdigital transducer electrode. The acoustic wave device can be a temperature compensated surface acoustic wave resonator configure to generate a surface acoustic wave.

[0010] The interdigital transducer electrode can include a bus bar that consists essentially of an arcuate section.

[0011] The interdigital transducer electrode can include a bus bar, in which the bus bar includes an arcuate section and a straight section.

[0012] Another example of this disclosure is an acoustic wave device that includes a piezoelectric layer and an interdigital transducer electrode on the piezoelectric layer. The interdigital transducer electrode includes a bus bar and fingers extending from the bus bar. The bus bar includes an arcuate section. The interdigital transducer electrode is configured to suppress a transverse spurious mode of the acoustic wave device.

[0013] The arcuate section can have a bend angle in a range from 1° to 20°. The arcuate section can have a bend angle in a range from 10° to 20°.

[0014] The bus bar can consist essentially of the arcuate section. The bus bar can include a straight section.

[0015] The acoustic wave device can further include a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave device.

[0016] The acoustic wave device can further include a temperature compensation layer over the interdigital transducer electrode. The acoustic wave device can further include a dispersion adjustment layer over the temperature compensation layer.

[0017] The acoustic wave device can further include a carrier substrate, in which the piezoelectric layer is over the carrier substrate. In some instances, the acoustic wave device can further include a dispersion adjustment layer positioned between the carrier substrate and the piezoelectric layer. Alternatively or additionally, the acoustic wave device can include an overlying dispersion layer positioned over the interdigital transducer electrode.

[0018] The acoustic wave device can be a surface acoustic wave resonator configure to generate a surface acoustic wave.

[0019] Another example of this disclosure is an acoustic wave filter that includes an acoustic wave resonator including a piezoelectric layer and an interdigital transducer electrode on the piezoelectric layer. The interdigital transducer electrode includes a bus bar and fingers extending from the bus bar. The bus bar includes an arcuate section. The acoustic wave filter also includes a plurality of additional acoustic wave resonators. The acoustic wave resonator and the additional acoustic wave resonators are together configured to filter a radio frequency signal.

[0020] The acoustic wave resonator can be a shunt acoustic wave resonator. The acoustic wave filter can be a band pass filter.

[0021] Another example of this disclosure is an acoustic wave device that includes a piezoelectric layer, an interdigital transducer electrode on the piezoelectric layer, and a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave resonator. The interdigital transducer electrode includes a bus bar and fingers extending from the bus bar. The bus bar includes an arcuate section. The interdigital transducer electrode is configured to suppress a transverse spurious mode of the acoustic wave resonator. The slow velocity boundary region has a slower velocity than a central portion of an active region of the acoustic wave device.

[0022] The arcuate section can have a bend angle in a range from 1° to 20°. The arcuate section can have a bend angle in a range from 10° to 20°.

[0032] The piston mode structure can include a portion of a second bus bar of the interdigital transducer electrode having a lower metal coverage ratio adjacent to an end portion of a finger of the fingers.

[0033] Another example of this disclosure is acoustic wave resonator that includes a piezoelectric layer, an interdigital transducer electrode on the piezoelectric layer, and a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave device. The interdigital transducer electrode includes a bent section arranged to create a curvature in a waveguide of the acoustic wave device to thereby suppress a transverse spurious mode of the acoustic wave device.

[0034] The bent section can have a bend angle in a range from 1° to 20°. The bent section can have a bend angle in a range from 10° to 20°.

[0035] The acoustic wave device can include a temperature compensation layer over the interdigital transducer electrode. The acoustic wave device can be a temperature compensated surface acoustic wave resonator configure to generate a surface acoustic wave.

[0036] The interdigital transducer electrode can include a bus bar that consists essentially of an arcuate section. The interdigital transducer electrode can include a straight section.

[0037] The piston mode structure can include an end portion of a finger of the fingers, in which the end portion includes wider metal than other portions of the finger. The piston mode structure can include an end portion of a finger of the fingers, in which the end portion includes thicker metal than other portions of the finger.

[0038] The piston mode structure can include an oxide over an end portion of a finger of the fingers.

[0039] The piston mode structure can include dispersion adjustment layer over a central portion of an active region of the interdigital transducer electrode, in which the dispersion adjustment layer is configured to cause a magnitude of a velocity in the central portion of the active region to be greater than the velocity in the boundary region of the acoustic wave device. The dispersion adjustment layer can be a silicon nitride layer. There can be a trench in the dispersion adjustment layer in the boundary region.

[0040] The piston mode structure can include a portion of a second bus bar of the interdigital transducer electrode having a lower metal coverage ratio adjacent to an end portion of a finger of the fingers.

[0041] The acoustic wave resonator of claim **Error! Reference source not found.** wherein the piston mode structure includes a portion of a second bus bar of the interdigital transducer electrode having a lower metal coverage ratio adjacent to an end portion of a finger of the interdigital transducer electrode.

[0042] Another example of this disclosure is an acoustic wave filter that includes acoustic wave resonators. The acoustic wave resonators include an acoustic wave resonator in accordance with any suitable principles and advantages disclosed herein. The acoustic wave filter is configured to filter a radio frequency signal.

[0043] The acoustic wave resonator can be a shunt acoustic wave resonator. The acoustic wave filter can be a band pass filter.

[0044] The acoustic wave filter can be included in a wireless communication device that also includes an antenna in communication with the acoustic wave filter.

[0045] Another example to this disclosure is a method of filtering a radio frequency signal. The method includes providing the radio frequency signal to an acoustic wave filter that includes a bent acoustic wave resonator. The method includes filtering the radio frequency signal with the acoustic wave filter. The method also includes during the filtering, suppressing a transverse spurious mode of the bent acoustic wave resonator. The bent acoustic wave resonator includes a bent section arranged to create a curvature in a waveguide of the bent acoustic wave resonator to thereby suppress the transverse spurious mode.

[0046] For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the innovations have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment. Thus, the innovations may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

WHAT IS CLAIMED IS:

1. An acoustic wave device comprising:

a piezoelectric layer; and

an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bent section arranged to create a curvature in an acoustic aperture of the acoustic wave device to suppress a transverse spurious mode of the acoustic wave device, the interdigital transducer electrode including a bus bar and fingers in the bent section extending from the bus bar, the fingers having substantially the same length throughout the bent section.

2. The acoustic wave device of claim 1 wherein the bent section has a bend angle in a range from 1° to 20°.

3. The acoustic wave device of claim 2 further comprising a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave device, the slow velocity region having a slower velocity than a central portion of an active region of the acoustic wave device.

4. The acoustic wave device of claim 1 wherein the bent section has a bend angle in a range from 10° to 20°.

5. The acoustic wave device of claim 1 wherein the acoustic wave device is a temperature compensated surface acoustic wave resonator configure to generate a surface acoustic wave.

6. The acoustic wave device of claim 1 wherein the bus bar consists essentially of an arcuate section.

7. The acoustic wave device of claim 1 wherein the bus bar includes an arcuate section and a straight section.

8. An acoustic wave device comprising:

a piezoelectric layer; and

an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bus bar having an arcuate section and fingers extending from at least the arcuate section of the bus bar, the fingers having substantially the same length throughout the arcuate section, and the acoustic wave device having a curved acoustic aperture configured to suppress a transverse spurious mode of the acoustic wave device.

9. The acoustic wave device of claim 8 wherein the arcuate section has a bend angle in a range from 1° to 20°.

10. The acoustic wave device of claim 8 wherein the arcuate section has a bend angle in a range from 10° to 20°.

11. The acoustic wave device of claim 8 wherein the bus bar consists essentially of the arcuate section.

12. The acoustic wave device of claim 8 wherein the bus bar includes a straight section.

13. The acoustic wave device of claim 8 further comprising a piston mode structure arranged to create a slow velocity boundary region of the acoustic wave device, the slow velocity region having a slower velocity than a central portion of an active region of the acoustic wave device.

14. The acoustic wave device of claim 8 further comprising a temperature compensation layer over the interdigital transducer electrode.

15. The acoustic wave device of claim 14 further comprising a dispersion adjustment layer over the temperature compensation layer.

16. The acoustic wave device of claim 8 further comprising a carrier substrate, the piezoelectric layer being over the carrier substrate.

17. The acoustic wave device of claim 8 further comprising a carrier substrate and a dispersion adjustment layer, the dispersion adjustment layer positioned between the carrier substrate and the piezoelectric layer.

18. The acoustic wave device of claim 8 wherein the acoustic wave device is a surface acoustic wave resonator configure to generate a surface acoustic wave.

19. An acoustic wave filter comprising:

an acoustic wave resonator including a piezoelectric layer and an interdigital transducer electrode on the piezoelectric layer, the interdigital transducer electrode including a bus bar with an arcuate section and fingers extending from at least the arcuate section of the bus bar, the fingers having substantially the same length throughout the arcuate section, and the acoustic wave resonator having a curved acoustic aperture configured to suppress a transverse spurious mode; and

a plurality of additional acoustic wave resonators, the acoustic wave resonator and the additional acoustic wave resonators are together configured to filter a radio frequency signal.

20. The acoustic wave filter of claim 19 wherein the acoustic wave resonator is a shunt acoustic wave resonator.